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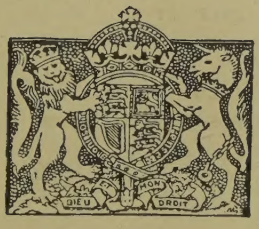

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ORIGINAL ARTICLES

NOMENCLATURE OF OLEIFEROUS BRASSICAS CULTIVATED IN THE PUNJAB*

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(Received for publication on 28 February 1945)

The oleiferous brassicas cultivated in the Punjab, or in India, are divided into three groups, locally known as *rai* (mustard), *sarson* (colza) and *toria* (rape). In the Punjab, or for that matter in different provinces or tracts of India, the various forms of these three crops have definite local names which are readily understood in the provinces or tracts of their origin but are unintelligible to people of alien areas. Therefore when it is desired to make the identity of a particular plant known or understood over a wide area, it is a general rule to apply the scientific name to it. In some cases, however, the scientific nomenclature is highly confusing and it is not easy to decide as to what particular scientific name should be used for a certain plant. This confusion is partly due to the same plant having been given different scientific names by different workers ignorant of each other's labours, but as pointed out by Bailey [1922] the following causes, among others, appear to be mainly responsible for the chaotic nomenclature of brassicas :

(*a*) Inclusion of too many forms in one species, thereby weakening the definitions.

(*b*) Attempts to identify oriental cultivated brassicas with species known in Europe.

(*c*) Mixing of seeds.

Bailey's paper deals mainly with the cultivated brassicas of China and Japan. Although he grew some of the Indian brassicas, he has not given any account of these as he agrees with the classification given by Prain [1898].

Prain, in his classic monograph, has described the confusion prevalent in his time with regard to the use of local and scientific names, and has straightened out the nomenclatorial tangle to a great extent. It has, however, been felt by later workers that the position in respect of at least two of the cultivated Indian brassicas, viz. *sarson* and *toria*, has not been sufficiently clarified.

The chief object of the present paper is to dispel the existing confusion and, in the light of the latest knowledge, to decide as to what scientific names should be applied to the brassicas cultivated in the Punjab. And since the brassicas grown in this Province are also cultivated, to a greater or less extent, all over India, the decisions arrived at will naturally be applicable to the brassicas cultivated throughout India. It is not proposed to make, in this contribution, any definite statements with regard to the affinities or relationships of the plants under consideration.

Oleiferous brassicas cultivated in the Punjab

As already stated, the oleiferous brassicas cultivated in the Punjab are divided into three main groups—*rai*, *sarson* and *toria*. There are several characteristics peculiar to each group, but they can easily be distinguished from each other on the basis of leaf characters.

In *rai*, the leaves do not clasp the stem, while in *sarson* and *toria*, with the exception of the lowermost two or three, they are amplexicaul. In *sarson* the leaves, at least the lower ones, are always more or less hispid, and so also is the lower part of the stem, while in *toria* both stem and leaves are glabrous.

Three forms of *rai*, two of *sarson* and one of *toria* are recognized in the Punjab. *Toria* is sometimes sub-divided into two kinds (*a*) tall and late and (*b*) dwarf and early, but as will be shown later these differences are purely due to soil and climatic conditions and have no taxonomic status. Therefore from the standpoint of a systematic botanist there is only one form of *toria*.

Method of study

Three forms of *rai*, two of *sarson* and one of *toria* were for some years grown at the Oilseed Breeding Farm, Lyallpur, and later for a season in the Experimental Area of Professor R. Ruggles Gates, F.R.S., in the Regent's Park, London. The plants belonging to different forms of these three crops were studied from germination till maturity. Specimens were taken at different stages of growth, and were later compared, for the purpose of identification, with the specimens stocked in the Royal Herbarium, Kew, where opportunity was also taken of discussing, with the taxonomists dealing with Indian plants, the best plan for

*Part I (in a modified form) of a thesis approved for the Degree of Master of Science of the University of London.

satisfactorily solving the nomenclatorial tangle of Indian brassicas. It may be noted that in the present contribution only those characters have been taken into consideration which, through long observation and study under radically different environmental conditions, have been found to be constant and non-variable and thus to be of taxonomic value.

Identification of oleiferous brassicas cultivated in the Punjab

1. *Rai* (mustard)

The three forms of *rai* cultivated in the Punjab are locally known as (*a*) *raya*, (*b*) *rai* and (*c*) *poorbi rai*.

(*a*) *Raya*. This is the plant which Roxburgh [1832] described as *Sinapis ramosa*, and which Hooker and Thompson [1861] described as *Brassica juncea*. It has been described by Prain on page 47 of his monograph as *Brassica juncea* subsp. *juncea*, var. *oleifera*.

Prain thinks that this plant found its way into India from China through a north-eastern route and that its immigration to India has been independent of any Aryan incursion. Sinskaia [1928] has confirmed this view and has shown that the native country of *B. juncea* is Asia, the centre of diversity of forms being China. *B. juncea* is cultivated in Afghanistan as well and, after a comparative botanical study of various Afghanistan mustards, Vavilov and Bukinich [1929] have concluded that *B. juncea* has found its way into Afghanistan from India. All the above opinions point to the conclusion that *B. juncea* was originally introduced from China into north-eastern India whence it has gradually extended to Afghanistan, most probably via Punjab.

(*b*) *Rai*. This is *Brassica tournefortii* Gouan., which is the same thing as *Brassica stocksii* H.f. & T. Specimens of this plant were collected by Thompson from cultivated fields in 1843 near Ludhiana and in 1846 near Dharamkot (Ferozepur district). He also collected a solitary specimen near Jhang. Later in 1922, Mr J. R. Drummond sent another specimen from Sirsa (Hissar district). All these specimens are stocked in the Royal Herbarium, Kew. It may be noted that all the above-mentioned places of collection are situated in the Punjab.

Prain has not given any detailed account of this plant in his monograph, as it was not found by him to occur in the then constituted province of Bengal—the area now covered by the provinces of Bengal, Bihar and Orissa. Sabnis and Phatak [1935] also have made no mention of this plant in their classification of cultivated Indian mustards presumably because this mustard is not grown in the area covered by their studies. The information to hand shows that this plant has not been known to extend eastwards beyond Delhi and Ajmer. It has, however, been reported to be under cultivation in western Tibet and to extend westwards to Italy and Spain. In the Punjab itself this form is commonly grown on the borders of fields in the central districts, which may be regarded as centres of ancient agriculture. It, therefore, seems highly probable that it has been under cultivation in the Punjab for a very long time, perhaps much longer than the other two forms of *rai*. It appears to have been introduced into the Punjab through a north-western route.

Nothing definite is known about its origin but it is believed by Prain to have originated in the Oriental or Mediterranean areas. The recent intensive studies carried out by the Russian school of workers on some oleiferous plants have shown that cultivated mustards and colzas have originated from weeds, perhaps independently in different regions. It appears likely that this form, like *Eruca sativa* Lam., has two independent centres of origin, Asiatic and Mediterranean.

(*c*) *Poorbi rai*. This plant is *Brassica nigra* Koch. It resembles in many respects the forms belonging to the geographical 'Eastern group' of Sinskaia, and in a greater degree the form described by her as *B. nigra* var. *orientalis* which is cultivated in Asia Minor.

With the present state of our knowledge it is not possible to venture any opinion about the introduction of this form into India. In the Punjab its cultivation is mainly confined to some parts of south-eastern districts, where it seems to have been introduced from districts situated farther east.

(*d*) *Brassica alba*. It is, at present, practically unknown in the Punjab. During the year 1926-27 an extensive and comprehensive collection of seed-samples of mustards was made from all over the Punjab, but none of these samples was found to be that of *B. alba*. Prior to 1927, however, this form used to be grown in the Botanical Experimental Area, Lyallpur, its seed having been originally obtained from outside the province. Hooker and others [1872] mention that Thompson came across cultivated fields of *B. alba* at Ferozepur in the Punjab. If this information is correct, the cultivation of *B. alba* must have ceased since, as now it is not grown at all in the Punjab.

2. *Sarson* (colza) *and toria* (rape)

Two forms of *sarson*, locally known as (*a*) *pili* (yellow-seeded) and (*b*) *kali* (brown-seeded) *sarson*, are cultivated in the Punjab. There exists a great deal of confusion about the naming of these forms and workers on these crops have, therefore, often

employed a diversity of botanical names while referring to these plants. So far as *toria* is concerned the present-day workers generally apply to this plant the name *Brassica napus* L., var. *dichotoma* Prain, but, as will be shown later, the use of this name is not valid. As *toria* resembles the brown-seeded form of *sarson* rather closely in morphological and some physiological characters, it is proposed to discuss it along with the two forms of *sarson*.

The yellow-seeded form of *sarson* cultivated in the Punjab has two-chambered, erect pods. In *Floras of India*, however, forms with three-valved, nodding fruits, and with four-valved, erect fruits have also been described. This multi-valved character of the fruit has been given specific rank by some workers. Prain in his monograph has discussed in detail the taxonomic value of this character, and the author has also seen specimens in the Royal Herbarium, Kew, and in the extra-provincial collection of yellow-seeded *sarson* at Lyallpur, where two- and four-valved pods occur on the same plant. He, therefore, agrees with Prain that, other things being equal, these differences are not more than racial. Prain's collection also included a two-valved, nodding-fruited form, which had not been mentioned by any previous worker.

It has already been stated that the taxonomists disagree widely in the systematic treatment of these brassicas. The following is a brief account of the names applied by different taxonomists to yellow-seeded and brown-seeded forms of *sarson*, and to *toria*.

Roxburgh treated the two-valved, erect-fruited form of yellow-seeded *sarson* as one species (*Sinapis glauca*) and the nodding-fruited, three-valved form as another (*S. trilocularis*). He named *toria* as *S. dichotoma*.

Hooker and Thompson lumped the two-valved, erect-fruited form of yellow-seeded *sarson* (*S. glauca* of Roxburgh) and *toria* (Roxburgh's *S. dichotoma*) into one group and referred to it as *Brassica campestris*. Later, Hooker and others termed it as *Brassica campestris* subsp. *napus*. They considered the 3-4-valved, nodding-fruited form as one species (*Brassica trilocularis*) and the 4-valved, erect-fruited form as another (*B. quadrivalvis*).

Duthie and Fuller [1882] regarded the two-valved, erect-fruited form of yellow-seeded *sarson* as *B. campestris* subsp. *napus*, var. *glauca*; the 3-4-valved, nodding-fruited form as var. *trilocularis*, and the four-valved, erect-fruited form as var. *quadrivalvis*. They also regarded brown-seeded *sarson* and *toria* as varieties of *B. campestris* subsp. *napus* and christened them var. *dichotoma* and var. *toria*, respectively. Their var. *dichotoma*, so these workers say, is the *S. dichotoma* of Roxburgh. Actually, however, Roxburgh's *S. dichotoma* is not precisely the equivalent of Duthie and Fuller's var. *dichotoma*, as Roxburgh's description applies to *toria* which has *glabrous* leaves, and Duthie and Fuller's to brown-seeded *sarson* which has *hispid* leaves. In fact, Roxburgh does not seem to have described the brown-seeded form of *sarson* at all. Duthie and Fuller in this case seem to have placed too much reliance on the judgment of Royle [1839], who quoted the name of *S. dichotoma* Roxb. for *kali* (brown-seeded) *sarson*. Royle's quotation of synonyms and his judgment, however, are faulty as he names *toria* as *S. glauca* Roxb., which latter appellation is applicable only to a form of yellow-seeded *sarson*. Furthermore, Duthie and Fuller's description of var. *dichotoma* does not refer to the taller and later kind of *toria* as Prain supposes. It without doubt refers to brown-seeded form of *sarson* which has hispid leaves. No doubt two kinds of *toria* are sometimes recognized, but none of them ever has hispid leaves. In the Punjab a kind of *toria* known as *sathri* is cultivated in some parts of the Multan district. This kind differs from ordinary *toria* in being shorter in stature and earlier in maturity and also in having slightly smaller leaves. The author has had the opportunity of growing and studying this form at Lyallpur, where taller and later kind of *toria* is exclusively grown, and also of growing and studying the latter kind at Multan. It was found that at both these places the newly introduced sorts (grown in sequestered places to prevent cross-pollination with other sorts) soon lost their identity and attained a close conformity with the native sort, showing thereby that the differences in size and maturity were due to climatic and/or soil conditions. Duthie and Fuller's description of var. *toria*, of course, fits in better with the dwarf and earlier kind, but, as is clear from the case cited above, dimensional proportions alone are of no taxonomic value in this case.

Watt [1889] mainly adopted the nomenclature proposed by Duthie and Fuller, but suggested that brown-seeded *sarson*, on account of having hispid leaves, should be placed in subsp. *campestris*, and that *toria*, on account of having glabrous leaves, should be viewed as belonging to subsp. *napus*. He, however, erroneously regarded Duthie and Fuller's vars. *trilocularis* and *quadrivalvis* as abnormal forms of Roxburgh's *S. dichotoma*.

Prain combined the forms of yellow-seeded *sarson* having (*a*) 2-valved, erect fruits, (*b*) 2-valved, nodding fruits, (*c*) 3-4-valved, nodding fruits, and (*d*) 4-valved, erect fruits, with the brown-seeded *sarson* into one comprehensive group which he called *Brassica campestris* var. *sarson*.

In the systematic synopsis in his monograph he treated *toria* as *Brassica campestris* subsp. *napus* var. *oleifera*, but adopted the term *dichotoma* on account of its priority. Further, because of marked differences in the time of growth, mode of cultivation, etc., of *sarson* and *toria* he considered it expedient to regard *toria* (subsp. *napus*) as a distinct species. The upshot of all these considerations was that he finally named *toria* as *Brassica napus* var. *dichotoma*.

Later, Duthie [1903] abandoned the nomenclature he had previously proposed in collaboration with Fuller and adopted the names suggested by Prain. But he applied the name *B. campestris* L., var. *sarson* Prain, to the yellow-seeded *sarson* only, and *B. napus* L., var. *dichotoma* Prain, to both brown-seeded *sarson* and *toria*. This use of a single appellation for both brown-seeded *sarson* and *toria* by Duthie was probably the outcome of the erroneous statement made by Prain (already mentioned) that var. *dichotoma* of Duthie and Fuller (which actually referred to brown-seeded *sarson*) was the taller and later kind of *toria*. Once again, Duthie seems to have been misled by the wrong quotation of synonymy.

That Prain's *B. campestris* var. *sarson* refers to both yellow- and brown-seeded forms of *sarson* is clear from the fact that Prain described the seed colour as 'dingy white, yellow or brown'. He further described *sarson* as a hairy-leaved, and *toria* as a glabrous-leaved, sort. Furthermore, he stated that *sarson* is cultivated mixed with other crops, and that *toria* is always grown alone. All these statements point definitely to the conclusion that he included both the yellow- and brown-seeded forms in the epithet *B. campestris* var. *sarson*. This has also been the opinion of most workers in India. For example, the specimens of both yellow-seeded and brown-seeded *sarson* sent by the Imperial Economic Botanist, Pusa, to the Royal Herbarium, Kew, were labelled *B. campestris* var. *sarson*, Prain. Mohammad, Singh and Alam [1931] and several other workers have also applied the name *B. campestris* var. *sarson* Prain, to both these forms of *sarson*.

For the sake of quick comprehension different systematic names that have been applied to yellow-seeded *sarson*, brown-seeded *sarson* and *toria* by various taxonomists are given in Table I.

Differences between yellow-seeded *sarson*, brown-seeded *sarson* and *toria*

For facility of presentation differences between yellow-seeded *sarson* and brown-seeded *sarson* have been first enumerated and set out in Table II, and then the differences between brown-seeded *sarson* and *toria* have been recounted and given in Table III.

Table I

Some of the systematic names that have been applied to yellow-seeded sarson, *brown-seeded* sarson, *and* toria

Authority	Yellow-seeded *sarson*	Brown-seeded *sarson*	*Toria*
Roxburgh	*Sinapis glauca* *S. trilocularis*	*S. dichotoma?*	*S. dichotoma*
Hooker and Thompson	*Brassica campestris* *B. trilocularis* *B. quadrivalvis*	*B. campestris*	*B. campestris*
Hooker and others	*B. campestris*, subsp. *napus* *B. trilocularis* *B. quadrivalvis*	*B. campestris*, subsp. *napus*	*B. campestris*, subsp. *napus*
Duthie and Fuller	*B. campestris*, subsp. *napus*, var. *glauca* *B. campestris*, subsp *napus*, var. *trilocularis* *B. campestris*, subsp. *napus*, var. *quadrivalvis*	*B. campestris*, subsp. *napus*, var. *dichotoma*	*B. campestris*, subsp. *napus*, var. *toria*
Watt	*B. campestris*, subsp. *napus*, var. *glauca* Regards vars. *trilocularis* and *quadrivalvis* as abnormal forms of Roxburgh's *S. dichotoma*	*B. campestris*, subsp. *campestris*, var. *dichotoma*	*B. campestris*, subsp. *napus*, var. *toria*
Prain	*B. campestris*, var. *sarson*	*B. campestris*, var. *sarson*	*B. napus*, var. *dichotoma*
Duthie	*B. campestris*, var. *sarson*	*B. napus*, var. *dichotoma*	*B. napus*, var. *dichotoma*

Discussion and conclusions

The extrorse or introrse nature of anthers seems to have escaped the notice of all taxonomists and early workers dealing with *sarson* and *toria* plants. It was in 1931, that Mohammad, Singh and Alam [1931] first noted this characteristic difference.

Prain, while lumping both yellow- and brown-seeded forms of *sarson* in one comprehensive species, did not attach any value to the colour of seeds, most probably due to the fact that his work related to Bengal where yellow-seeded form is almost exclusively grown and he, therefore, did not

TABLE II

Differences between yellow-seeded and brown-seeded forms of sarson

Yellow-seeded *sarson*	Brown-seeded *sarson*
1. Lowermost 1 – 2 leaves	
amina prominent up to the ery base of the leaf.	Lamina practically absent in the basal half.
2. Colour and texture of leaves	
ark glaucous, fleshy.	Pale glaucous, thin.
3. Branching	
ranches erect, ascending. raggling plants absent. ne angle at which the pri- ary branches arise varies om 10° to 20°.	Rather erect to spreading. Straggling plants occasionally present. The angle at which primary branches arise varies from 23° to 43°.
4. Corolla	
iameter from 14 × 15 mm. 17 × 16 mm. Average ngth of claw plus blade ·2 mm., length of claw 2 mm., and width of blade 1 mm. Potals narrow, with aces between the adjacent es.	Diameter from 15 × 15 mm. to 20×19 mm. Average length of claw plus blade 11·4 mm., length of claw 3·6 mm., and width of blade 7·1 mm. Petals broad, generally overlapping.
5. Anthers	
the bud as well as in the n flower all the six anthers rorse.	In the bud all six anthers introrse, but in an open flower the anthers of four median stamens extrorse, of two lateral stamens introrse.
6. Pods	
ick and broad, never rulose.	Thin and narrow, sometimes torulose.
7. Seeds	
ngy white, or yellow; non- ucilaginous.	Dark brown, brown, or reddish brown; mucilaginous.
8. Fertility	
lf-fertile.	Highly self-sterile.
9. Maturity	
least a week later in wering and maturity.	At least a week earlier in flowering and maturity.
10. Localities of cultivation	
own only in parts of walpindi and Kangra tricts of the Punjab.	Grown almost all over the Province.

TABLE III

Differences between brown-seeded sarson *and* toria

Brown-seeded *sarson*	*Toria*
1. Leaves and stem	
At least the lower leaves more or less hairy, and so also the lower part of the stem; leaves thin.	Leaves and stem glabrous; leaves somewhat fleshy.
2. Seeds	
Mucilaginous; generally there is a preponderance of darker coloured seeds in a sample.	Non-mucilaginous; generally lighter coloured seeds predominate.
3. Maturity	
When sown at the same time as *toria*, at least a fortnight later in flowering and maturity. In the Punjab it is a *rabi* (spring) crop, being sown in October-November and harvested in March-April.	When sown at the same time as brown-seeded *sarson*, at least a fortnight earlier in flowering and maturity. In the Punjab it is a *zaid kharif* (autumn) crop, being sown in September and harvested in December-January.
4. Cultivation and uses	
Grown almost all over the Province mixed with other crops, mostly on *barani* (rain-fed) areas. In addition to the extraction of oil from its seeds, used as fodder and vegetable. Oil is preferred for culinary purposes.	Always grown alone, almost entirely on irrigated areas. Exclusively grown for the extraction of oil from its seeds. Plants are not relished as vegetable, and oil is used for culinary purposes only if *sarson* oil is not available.

have an opportunity of studying thoroughly the brown-seeded form of *sarson*. No doubt he found some brown seeds in the samples of yellow-seeded *sarson* collected by him, but he erroneously concluded that since both sorts of seeds occurred in the same sample, the seed colour was of no taxonomic value. As pointed out by Bailey [1922], there is a need for great caution in formulating an opinion from the examination of seed-packets alone. The seeds obtained from market or from some other dubious source, in most cases, contain a mixture of more than one seed forms, and this mixing of seeds has been greatly responsible for the confusion prevalent in the nomenclature of cultivated brassicas. Prain's conclusion that seed colour is of no great import in the classification of brassicas is probably the outcome of this mixing of seeds. Duthie and Fuller also seem to have been misled by the same cause because while

describing the yellow-seeded *sarson* they mention the colour of seeds to be 'yellow, dark brown, or reddish brown'. To the same cause may be traced the erroneous conclusion that the forms of cultivated brassicas at times pass into one another. From his long experience of breeding work on yellow-seeded and brown-seeded forms of *sarson*, the author is convinced that if care is taken to avoid accidental mixing of seeds, the progeny of yellow or brown seeds is always 'true to type'. Studies carried out by some workers [Mohammad, Sikka and Aziz, 1942] have also shown that yellow and brown colours of seeds in the case of *sarson* are heritable characters. There is no doubt that on account of the prevalence of unfavourable weather conditions during maturity, or during post-harvest period when the crop is still lying in the field awaiting threshing, or through long storage the colour of seeds undergoes some change, but this change is not so radical as to lead to a confusion of identities and to give rise to the possibility of yellow seeds being mistaken for brown seeds. Therefore, there is ample evidence to believe that colour of seeds (yellow or brown) is, in the case of *sarson*, a *good* taxonomic character.

The confusion prevalent as regards the nomenclature of yellow-seeded *sarson*, brown-seeded *sarson* and *toria* has already been described in some detail in the preceding pages. From the differences enumerated in Tables II and III, it will be seen that the yellow-seeded *sarson* differs markedly from the brown-seeded *sarson*, or for the matter of that from *toria*, in morphological, physiological and ecological characteristics. Furthermore, the idea that intermediate forms sometimes exist is not supported by any authentic and unassailable evidence. Therefore, the yellow-seeded *sarson* deserves a specific rank and should be singled out as a separate species instead of being lumped with brown-seeded *sarson*. Sinskaia has also expressed the same opinion.

The differences between the brown-seeded *sarson* and *toria*, on the other hand, are not so great as to entitle them to be classed as different species, and both of these should, therefore, be treated as belonging to a single species. The next point to decide is as to whether these should be placed in species *B. napus* or *B. campestris*. Linne [1763] distinguished *B. napus* and *B. campestris* on the character of the root—'fusiformi' for *napus*, and 'tenui' for *campestris*. Later workers, however, have realized that this delimitation of the two species is not enough and has been a cause of great confusion. Sinskaia, after a detailed study, has given a list of characters on which the delimitation of the species *B. napus* and *B. campestris* should be based. A few of these characters, germane to the points at issue, are given in Table IV.

TABLE IV

Characters of the species B. napus *and* B. campestris

B. napus	*B. campestris*
Fertility	
Self-fertile	Highly self-sterile
Chromosome number	
$2n=36$	$2n=20$
Pubscence	
Strongly pubescent forms absent	Strongly pubescent forms present
Crossability with *B. glauca* Wittm.* (yellow-seeded sarson)	
Does not cross	Crosses readily
Geographical conditions	
Concentrated almost exclusively in Europe	Widely spread in Asia

Nagaharu and Nagamatsu [1932] tested the fertility of varieties of *B. napus* and *B. campestris*, and confirmed that the former is self-fertile, while the latter is mainly self-sterile.

Both brown-seeded sarson and *toria* are highly self-sterile, have chromosome number $2n=20$, and cross readily with yellow-seeded *sarson*. They both should, therefore, be treated as belonging to the species *Brassica campestris*.

The yellow-seeded *sarson* is self-fertile and has chromosome number $2n=20$, so that it partakes of some characteristics of both *B. napus* and *B. campestris* and, therefore, is in a class by itself. This is an additional reason for separating it as a distinct species.

Nomenclature. Having decided to regard the yellow-seeded *sarson* as a separate species and to treat brown-seeded *sarson* and *toria* as belonging to the species *B. campestris*, the next question is to decide as to what name should be applied to each of them.

Sinskaia has used the name *Brassica glauca* Wittm. for yellow-seeded *sarson* on the authority of Dr Wittmack, but she has made no reference to any publication wherein Dr Wittmack first applied this name to this form of *sarson*. Prain, while quoting, in his monograph, the synonym *B. glauca* Wittm. cited the *Kew Report* by Hooker [1877] as the source of his information. In this *Report*, however, the only statement that has been made by Hooker in this connexion is to the effect that Dr Wittmack has identified the seed of *Guzerat Rape* as the seed of *S. glauca* Roxb., and it is nowhere stated by Hooker that Dr Wittmack has applied the name *B. glauca* to

*As will be shown later the use of name *B. glauca* Wittm. for yellow-seeded *sarson* is not correct.

the yellow-seeded *sarson*. In the *Index Kewensis* also there is no mention of the name *B. glauca* as having been used by Dr Wittmack in connexion with some plant. The name *B. glauca*, as stated by Durand and Jackson [1906] in *Index Kewensis*, was first applied by Kuntze [1891] to a plant found in the Canary Islands. Evidently, therefore, Prain was mistaken in assuming that the name *B. glauca* was applied by Dr Wittmack to the yellow-seeded *sarson*, as the evidence available does not justify such an assumption. Sinskaia probably used this name on the authority of Prain. Since the name *B. glauca* has already been used by Kuntze for another plant, the application of this name to the yellow-seeded *sarson* is not at all valid. In order to decide as to what name should be applied to this form of *sarson* recourse must be had to the list of names given in Table I, and out of the several names listed there for this *sarson*, one having priority of application should be selected. It will be seen that Roxburgh was the first taxonomist to apply the name *S. trilocularis* to the form of yellow-seeded *sarson* having 3-celled pods. Later, Hooker and Thompson called the same form *Brassica trilocularis*. No doubt in both these cases this form was treated as a distinct species, and the later work has shown it to be only a race. But the fact remains that the appellation *trilocularis* has been used specifically to designate yellow-seeded *sarson* in some way, and therefore it must be adopted on account of its priority. Since the old generic distinction into *Sinapis* and *Brassica* has been given up on account of its artificiality and the practice now is to lump the two old genera into one, under the name *Brassica*, hence *Brassica trilocularis* H. f. & T. is the name that should be applied to the yellow-seeded *sarson*. It should, however, be considered to include all kinds whether they have 2-, 3-, or 4-valved and erect or nodding pods. It is realized that the use of the word *trilocularis* is not quite appropriate and is misleading to a certain extent but it has to be retained on account of its priority. In fact *International Rules of Botanical Nomenclature* [Briquet, 1935] outlaw the use of any other name but this for the yellow-seeded *sarson*. As pointed out by Higgins [1937] the only way to clear up the tangle of nomenclature is to follow these rules faithfully, and if some of the names which have been in use for a long time and have thus become familiar are found to be wrong according to these rules the only course to help towards a happier future and to bring order out of chaos is to accept the change with a good grace.

With regard to the brown-seeded *sarson* and *toria*, it has already been shown that they should be treated as belonging to the species *Brassica campestris*. With the present state of our knowledge it is not yet possible to appraise fully the taxonomic value of the differences in the cultivation of crops. Sinskaia has suggested the term 'cultivated ecotypes' for the forms differing in their mode of cultivation. An ecotype, from her point of view, is equivalent to a 'variety'. The present-day tendency [Stout, 1940], however, is to assign to a group a rank commensurate with the differences it exhibits from other allied groups. Applying this basis and taking into consideration all the differences mentioned in Table III, it appears best to treat the brown-seeded *sarson* and *toria* as belonging to different subspecies of a single species. Watt suggested that the brown-seeded *sarson* should be regarded as subspecies *campestris*, and *toria* as subspecies *napus* of *B. campestris*. This suggestion of his fully meets the requirements of the point under consideration and should, therefore, be accepted. Hence the brown-seeded *sarson* should be christened as *Brassica campestris* L., subsp. *campestris*, var. *dichotoma* Watt., and *toria* as *Brassica campestris* L., subsp. *napus*, var. *toria* D. & F. Since the latter name was first proposed by Duthie and Fuller, it has been retained on their authority. Diagnostic characters, brought up-to-date, of yellow-seeded *sarson*, brown-seeded *sarson* and *toria* are given in Appendix I.

In conclusion it may be pointed out that in view of the recent work on the delimitation of *B. campestris* and *B. napus* and in view of the edicts of the *International Rules of Botanical Nomenclature*, Prain's nomenclature *B. campestris* var. *sarson* for both the yellow-seeded and the brown-seeded forms of *sarson*, and *B. napus* var. *dichotoma* for *toria* should be abandoned.

As regards the introduction of these forms into the Punjab, it may be noted that recent and exhaustive studies carried out by the Russian workers have shown that eastern Afghanistan together with the adjoining north-western India is one of the independent centres of origin of *B. campestris*. From the fact that both the brown-seeded *sarson* and *toria* resemble rather closely one or other of the groups of Afghanistan *B. campestris* isolated by Sinskaia, and from the availability of Persian synonyms for these crops, it is pretty certain that both brown-seeded *sarson* and *toria* have been introduced from the north-west into the Punjab, wherefrom they have extended eastwards into India.

The yellow-seeded *sarson*, on the other hand, is more commonly grown in the eastern provinces of India, where it exhibits a diversity of form. It is highly probable that further work might reveal its centre of origin in north-eastern India or in China. In the Punjab, however, it appears to have been introduced from the east.

Summary

1. The three oleiferous brassicas cultivated in the Punjab are locally known as *rai*, *sarson* and *toria*.

2. Three forms of *rai* are cultivated in the Punjab and bear the local names (*a*) *raya*, (*b*) *rai* and (*c*) *poorbi rai*. These have been identified as (*a*) *Brassica juncea* H. f. & T., (*b*) *Brassica tournefortii* Gouan., and (*c*) *Brassica nigra* Koch., respectively.

3. The appalling confusion prevalent about the nomenclature of two forms of *sarson*, viz. (*a*) yellow-seeded and (*b*) brown-seeded, and of *toria* has been described, and the validity of scientific names proposed for these plants by various taxonomists has been discussed.

Differences between these plants have been enumerated and it has been shown that the yellow-seeded *sarson* should be classed as a distinct species, and that it is not valid to apply to it any other name than *Brassica trilocularis* H. f. & T. The brown-seeded *sarson* and *toria*, on the other hand, should be regarded as subspecies of *B. campestris* and the names *Brassica campestris* L., subsp. *campestris*, var. *dichotoma* Watt., and *Brassica campestris* L., subsp. *napus*, var. *toria*, D. & F., should be applied, respectively, to these plants.

It has been suggested that Prain's nomenclature for the two forms of *sarson* and for *toria*, which has gained general acceptance, should be abandoned as it (besides being out of tune with the latest taxonomic knowledge) runs counter to the procedure suggested in the *International Rules of Botanical Nomenclature*.

4. *Brassica juncea* H. f. & T., *Brassica nigra* Koch., and *Brassica trilocularis* H. f. & T. appear to have been introduced into the Punjab through an eastern route ; while *Brassica tournefortii* Gouan., *Brassica campestris* L., var. *dichotoma* Watt., and *Brassica campestris* L., var *toria* D. & F. are immigrants from the north-west.

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Appendix I

Diagnostic characters of the yellow-seeded *sarson*, the brown seeded *sarson* and *toria*

(*a*) Brassica trilocularis *H. f. & T. vern.* pili (*yellow-seeded*) sarson

An annual, 3-5 ft. high, plant with ascending branches. *Root* slender, tapering. *Leaves*, lamina extending to the base in all; the lower lyrate-pinnatipartite, upper smaller, lyrate-sinuate to lanceolate, entire; all except the lower 3-4 auricled, stem-clasping; dark green, glaucous, rather fleshy, more or less hairy—at least the lower ones. *Flowers* in oblong corymbs elongating into racemes. *Sepals* dark green, glaucous, turning yellow before falling. *Petals* yellow, narrow, about 0·5 cm. broad, well separated from one another. *Anthers* all introrse in bud and flower. *Pod* laterally compressed, much broader than thick, about 0·7 cm. broad, not torulose; usually 2-valved or spuriously 3-4 valved, erect or pendent; valves thickly leathery; beak conical, stout. *Seeds* sub-globose, dingy white or yellow, nearly smooth, non-mucilaginous. Self-fertile. Late in maturity.

(*b*) Brassica campestris *L., sub-sp.* campestris, *var.* dichotoma *Watt. vern.* kali (*brown-seeded*) sarson

An annual, 3-5 ft. high, plant with ascending, medium, or spreading branches. *Root* slender, tapering. *Leaves*, lamina in the lowermost 1-2 practically absent in the basal half; the lower lyrate-pinnatipartite, decreasing upwards, upper smaller, triangular-lanceolate, entire; all except the lower 3-4 auricled, stem-clasping; green, glaucous, thin, more or less hairy—at least the lower ones, and also the lower part of the stem. *Flowers* in oblong corymbs elongating into racemes. *Sepals* green, glaucous, turning yellow before falling. *Petals* bright yellow, rarely pale yellow to whitish, broad, about 0·7 cm. wide, generally overlapping. *Anthers* in the bud all introrse, in the open flower those of the four median stamens extrorse, of the two lateral ones introrse. *Pods* rather narrow, about 0·5 cm. broad,

metimes torulose; 2-valved, erect; valves thin; beak rrowly conical. *Seeds* sub-globose, dark brown, brown, reddish brown, finely rugose, mucilaginous. Highly lf-sterile. Late in maturity.

(*c*) Brassica campestris *L.*, *sub-sp.* napus, *var.* toria *& F. vern.* toria.

An annual, 2-5 ft. high, plant with ascending, medium, spreading branches. *Root* slender, tapering. *Leaves*, mina in the lowermost 1-2 practically absent in the sal half; the lower lyrate-pinnatipartite, decreasing wards, upper smaller, triangular-lanceolate, entire; except the lower 3-4 auricled, stem-clasping; green, glaucous, somewhat fleshy, quite glabrous, so also the stem. *Flowers* in oblong corymbs elongating into racemes. *Sepals* green, glaucous, turning yellow before falling. *Petals* bright yellow, rarely pale yellow to whitish, broad, about 0·7 cm. wide, generally overlapping. *Anthers* in the bud all introrse, in the open flower those of the four median stamens extrorse, of the two lateral ones introrse. *Pods* rather narrow, about 0·5 cm. broad, sometimes torulose; 2-valved, erect; valves thin; beak narrowly conical. *Seeds* sub-globose, dark brown, brown, or reddish brown, finely rugose, non-mucilaginous. Highly self-sterile. Early in maturity.

A NOTE ON THE ESSENTIAL OIL OF MUSTARD IN *BRASSICA* SPECIES AND *ERUCA SATIVA*

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HE seeds of *Brassicae* are known to contain a ucoside called sinigrin or potassium myronate. n hydrolysis, under the influence of an enzyme, yrosin, which is also localized in the different lls of the seeds, this glucoside yields dextrose, sential oil of mustard (chemically termed allyl-o-thio-cyanate), and potassium hydrogen sulphate cording to the following reaction:

$$C_{10}H_{16}O_9NS_2K + H_2O = C_6H_{12}O_6 + C_3H_5NCS + KHSO_4$$

Sinigrin — Water — Dextrose — Allyl-iso-thio-cyanate — Potassium hydrogen sulphate

The essential oil of mustard is colourless, has an tensely pungent odour and an acrid taste. It a powerful irritant, and causes very rapid sication when applied to the skin.

The distribution of sinigrin in the different ecies of *Brassica* has a great economic importance. he disinclination shown by cattle to feed on reen fodder of certain oleiferous *Brassicae* or on rtain mustard seed cakes is mainly due to the ritating effects of this essential oil. The deter-ination of mustard oil in seed cakes is, therefore, considerable practical importance.

During the last few years the Oilseeds Section Lyallpur, has been engaged on the evolution of w varieties of oilseeds and the funds provided the Imperial Council of Agricultural Research ve given impetus to this work. As a result of reliminary studies carried out an attempt has en made to classify the different species concerned cording to their essential oil content, and the resent note besides suggesting a new line of work is intended to describe the results obtained during the two years 1942-43 and 1943-44.

A review of literature shows that very little work has so far been done on this subject. Athawale, Hare Duke and Mathur [1938] published some results on the industrial aspects of the production of fixed oils with a desirable pungent smell in compliance with the demand of the Indian markets, but these have a remote bearing on the present problem.

Method of estimation and sampling of plant material

The volatile oil of mustard is prepared by distillation of the ground material macerated with tepid water for some hours so as to allow the myrosin to hydrolyse the glucoside present [Allen 1930]. In the present studies the method employed for the estimation was the same as that described by Athawale *et al* [1938] with slight modifications to suit the conditions of the experiment.

Five gm. in case of the seed and 25 gm. in case of stem, branches and leaves were thoroughly crushed and mixed with about 1 gm. of Kieselguhr to destroy the cellular structure. The mixture was transferred into a conical flask with 100 c.c. of water and kept at a temperature of 30°-40°C. for about four hours during which period 20 c.c. of alcohol were added to prevent frothing. The mixture was then distilled as rapidly as possible into 10 c.c. of 10 per cent ammonia till 2/3rd of the water content of the mixture was distilled over. With ammonia the essential oil forms a solid non-volatile compound. Twenty c.c. of $\frac{N}{10}$ silver nitrate were then added and the mixture

TABLE I

Percentage of allyl-iso-thio-cyanate (essential oil of mustard) on dry basis in the developing ovules of Brassica *species and* taramira *crops (average of two years 1942-43 and 1943-44)*

Number of days after flowering	*Toria*		Brown *sarson*		*Raya* L-16		*Raya* L-18		*Taramira*	
	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard
10 days	77·5	1·28	81·1	1·09	77·8	1·91	76·6	2·17	76·8	2·21
20 „	81·7	1·32	76·5	0·81	82·3	1·84	76·9	1·29	81·1	1·26
30 „	75·8	0·80	77·3	0·68	77·3	0·97	72·4	0·94	81·2	1·04
40 „	63·1	0·60	65·0	0·68	69·9	0·96	60·7	0·98	74·2	0·96
50 „	55·3	0·76	42·9	0·63	62·5	1·10	57·5	1·05	64·3	0·92
60 „	51·3	0·60	16·5	0·42	54·0	0·86	47·7	0·85	61·3	0·64
70 „	41·3	0·46	8·2	0·46	50·3	0·68	21·4	0·72	57·3	0·76

TABLE II

Percentage of allyl-iso-thio-cyanate (essential oil of mustard) on dry basis in various parts of Brassica *species and* taramira *crops at various stages of their growth (average of 2 years 1942-43 and 1943-44)*

Stage of plant at sampling	Name of the sample	*Toria*		Brown *sarson*		*Raya* L-16		*Raya* L-18		*Taramira*	
		Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard	Percentage of moisture	Percentage of essential oil of mustard
Tender stage	Leaves	89·3	0·59	89·9	0·52	89·0	0·71	89·8	0·62	90·1	0·72
Young stage	Stem	93·5	0·62	93·2	0·62	93·0	0·86	94·8	0·66	92·9	0·59
	Branches	92·3	0·59	92·4	0·49	92·3	0·67	93·2	0·70	91·9	0·55
	Leaves	89·8	0·35	90·7	0·34	87·4	0·45	91·1	0·47	90·3	0·33
Early blooming stage	Stem	88·1	0·34	89·8	0·34	91·2	0·60	90·3	0·47	91·6	0·39
	Branches	93·2	0·52	89·1	0·25	92·5	0·50	91·4	0·42	91·2	0·41
	Leaves	88·0	0·34	89·2	0·30	87·4	0·54	89·4	0·42	88·2	0·29
Mid blooming stage	Stem	82·2	0·12	85·6	0·13	81·6	0·21	80·1	0·25	81·7	0·22
	Branches	84·1	0·24	89·9	0·20	80·6	0·32	79·8	0·27	82·3	0·24
	Leaves	88·5	0·17	85·7	0·12	87·3	0·22	81·6	0·25	87·0	0·23
End of blooming stage	Stem	79·8	0·13	83·5	0·10	73·4	0·13	80·0	0·18	83·5	0·15
	Branches	76·5	0·11	81·9	0·11	69·7	0·13	79·0	0·18	81·3	0·13
	Leaves	86·5	0·14	83·7	0·11	84·7	0·21	82·9	0·19	84·6	0·19
Maturing stage	Stem	80·3	0·06	75·8	0·07	74·4	0·08	77·2	0·06	77·4	0·08
	Branches	73·9	0·06								

heated on a water bath for an hour. The silver sulphide produced was separated by filtration and the filtrate was rendered slightly acidic. The excess of silver was then titrated with $\frac{N}{10}$ ammonium thiocyanate solution. Each c.c. of $\frac{N}{10}$ silver nitrate consumed corresponds to 0·004956 gm. of allyl-iso-thio-cyanate.

The material for this investigation was obtained from *toria* (*Brassica napus* L. Var. *dichotoma* Prain), *raya* L-16 and L-18 (*Brassica juncea*), *rai* (*Brassica nigra*) and *taramira* (*Eruca sativa*) crops. Freshly opened flowers in a sufficiently large number were tagged in the case of each of the above crops and samples of developing ovules of known ages were obtained regularly at intervals of 10 days each. Besides the developing ovules, estimations of the essential oil were also made in leaves, stems and branches at various stages of their growth. For this purpose five plants were removed from each plot between 9 and 10 a.m. on each day of sampling and were divided into stem, branches and leaves. The results of these estimations (average of two years' data) are given in Tables I and II from which the following general conclusions are drawn :

(1) The essential oil content of the developing ovules (Table I), irrespective of the species, is the highest at the beginning of seed development and it goes on decreasing as the seeds advance in age. In the young ovules it has been found to be about three times the amount present near the time of maturity.

(2) Among the various species studied it was found (Table I) that *raya* L-16 and L-18 and *taramira* crops contained in the developing ovules a higher amount of essential oil at all the stages of their development than *toria* and brown *sarson*. This shows that the former crops contain a higher amount of sinigrin in the seeds at their various stages of development and this is responsible for their comparatively greater pungency.

(3) The mature seeds of *Brassica* species may be arranged in the following order in accordance with the degree of their pungency as determined by the essential oil percentage :

Rai (1·01), *raya* L-18 (0·80), *raya* L-16 (0·70), *toria* (0·62), Brown *sarson* (0·60).

It may, however, be noted that *taramira* contains the same amount of essential oil (0·71) as *raya*, possessing characteristic smell which can be easily distinguished from that of essential oil present in seeds of various *Brassicae* referred to above.

(4) Tender leaves contain a higher amount of essential oil than mature ones, it being about four times the amount present in the plants at the end of the blooming stage. Among the various species studied it was found that the essential oil in *raya* varieties is slightly higher than in *toria* and brown *sarson*. This difference is more pronounced in the later stages of growth than in the earlier. For example, in the young stages of growth the percentage excess in the essential oil in *raya* and *taramira* crops is about 23 per cent over *toria* and brown *sarson*, (as indicated by the average values of two years for both crops) but in the middle and concluding stages of blooming the excess is about 60 per cent (Table II).

(5) In the stem and branches the essential oil is at its maximum in the early stage of plant growth. Later on from the blooming stages onwards, however, considerable decrease in the essential oil content takes place. When the plants are very young, the differences between the various crops under study are imperceptible, but, with the advancement in ages, the differences become manifest. Higher amounts of essential oil persist in *raya* varieties in later stages of growth than in *toria* and brown *sarson* (Table II).

It may be pointed out that in the two years there are slight variations in the essential oil content in the developing ovules and in other parts. These variations may be attributed to errors in sampling or they may be seasonal variations. These, however, are of little consequence, since the general conclusions are based on two years' data, which show the same trend.

From the results of the essential oil content in various parts in these crops it is therefore concluded that the greater pungency in *raya* and *taramira* crops appears to be due to the presence of higher amounts of essential oil in the developing seeds as compared with those of *toria* and brown *sarson* crops. In the case of leaves, stem and branches this difference is less marked although the former crops tend to possess a higher amount of essential oil in these parts, particularly in leaves in the later stages of growth. Brown *sarson* having the least amount of essential oil is evidently more suited for fodder purposes than the other species.

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INFLUENCE OF AGRONOMIC TREATMENTS ON GINNING PERCENTAGE IN PUNJAB COTTONS

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Among the various economic attributes of the cotton plant, high yield, high ginning percentage and good quality of lint are evidently the most important. Of these, yield always takes precedence over others and in all centres where work on cotton improvement is being carried out, the consideration of yield has always ranked the foremost. The importance of this character has been fully brought out by Panse [1941] who finds that, to compensate for reduction in yield by 1 per cent, the variety must show an increase of 10 per cent in quality. As regards ginning percentage and quality, it is the experience of most cotton breeders that these two attributes are antagonistic and sometimes improvement in quality has been achieved at the cost of ginning percentage. It is, however, noteworthy that a loss of 1 per cent in ginning percentage eats up nearly 3 per cent of the price of the produce, which means that 1 per cent ginning outturn is equal to 3 per cent yield of the crop or 30 per cent in quality. In view of this, it is necessary that, in any programme of cotton improvement, ginning percentage must receive at least as great a weightage as the yield of the crop or the quality of its produce.

The primary characters which contribute to ginning percentage are the weight of lint and weight of seed, each of which is a complex character by itself, consisting of several sub-components. For instance, the weight of lint is composed of weight of single fibre and the number of fibres on a seed. The former character could be further split up into still finer components, such as fibre length and fibre weight per unit length. Similarly the important sub-components of seed weight are volume and the specific gravity of seed.

All the above mentioned characters are heritable but like all quantitative characters, each of them is subject to great variations under the stress of seasonal and agronomic factors also. The work of Balls [1912] in Egypt, Sturkie [1934] and Brown [1938] in America, and several others, has clearly revealed the great role played by nutrition, soil moisture, spacing, soil types, climate, etc., in modifying ginning percentage and its components. In India, however, such analysis has received but little attention from cotton workers, and the exact nature of factors, which bring about a reduction or increase in ginning percentage of varieties, is still not clearly understood. The only results reported on Indian cottons are those of Patel and Mankad [1923], Venkataraman [1930] and Sen [1934], who have studied the variations in some of the components of ginning percentage in progressive pickings of varieties, but no worker has so far attempted to analyse the bearing of the more commonly used agronomic treatments on this important character. The present investigation was undertaken with a view to filling up the latter gap in the knowledge about Punjab cottons, and an attempt has been made to study the variation in the ginning percentage of some *desi* and American varieties when they are grown under different irrigational, manurial, sowing date and spacing treatments. The results obtained in this study are embodied in the present paper.

Material and methods

The data for studying the effect of different irrigational and manurial treatments were gathered from the following experiments conducted by the Deputy Director of Agriculture, Lyallpur, during 1942-43 and 1943-44 on the Punjab-American cotton variety L.S.S. under the Water Requirement of Crops Scheme, Risalewala :

(*i*) Different number of irrigation experiments.
(*ii*) Different dates of irrigation experiments.
(*iii*) Experiments to study the effect of different intensities and frequencies of irrigation.
(*iv*) Flat versus ridge irrigation experiments.
(*v*) Manurial-cum-irrigational experiments.

All these experiments were carried out in accordance with the randomized block system with five to six replications.

The quantity of water applied at each irrigation was measured by first pumping the calculated quantity of water into a high level cistern and then letting out the water through cement concrete pipes into the beds. In this way, measured quantities of water were given to each bed without any loss.

The samples for appraising the effect of sowing dates and spacings were taken from two different complex experiments laid out during 1942-43 at the Cotton Research Farm, Risalewala. The details of the treatments included in these experiments are given later. Their layout was according to the split plot design.

The samples for determination of ginning percentage consisted of 3 lb. *kapas* taken separately from each of the replications in the above experiments.

Ginning of all samples was done by manual labour with wooden hand gins. Before ginning, the samples of *kapas* were conditioned for 24 hours in an air tight room artificially kept at a constant temperature (90°F.) and humidity (30 per cent). The lint obtained after ginning was also treated similarly before weighing it finally for the calculation of ginning percentage.

For determining the various components of ginning percentage, the following procedure was adopted :

(*a*) *Seed weight.* The combined seeds of all the replications were divided into 16 equal parts. Twenty-five seeds from each lot were then selected at random and mixed to form a representative sample of 400 seeds. This sample was weighed on a chemical balance and, from the total weight, the average weight of a single seed was calculated in miligrammes.

(*b*) *Lint per seed.* This was calculated by the following formula :

$$\frac{\text{Average weight of a single seed} \times \text{Ginning outturn}}{100 - \text{Ginning outturn}}$$

(*c*) *Mean fibre length.* This was found out by Ball's Sorter from representative samples drawn out of the mixed produce of all replications of the experiment.

(*d*) *Mean fibre weight.* This was calculated by weighing a known number of fibres on a quartz Torsion Micro-balance.

Experimental results

(A) *Effect of varying quantities of irrigation water*

The quantities of irrigation water tried in these experiments ranged from 9 to 24 acre-inches. These were applied in 3 to 8 irrigations, each of 3 in. depth.

The analysis of variance in these experiments revealed the effect due to irrigation as highly significant in both the years. The mean values of ginning percentage along with critical difference and order of merit of different treatments are given in Table I.

Table I

Mean values of ginning percentage in different number of irrigation experiments

Year	Number of irrigations						Critical difference (5 per cent)	Order of merit
	3	4	5	6	7	8		
1942–43	33·60	33·97	33·72	33·06	33·36	33·36	±0·40	4, 5, 3, 7, 8, 6
1943–44	31·25	30·64	30·18	30·00	29·70	29·43	±0·43	3, 4, 5, 6, 7, 8

The results show that, in 1942-43, four irrigations gave significantly higher ginning percentage than six, seven and eight irrigations, though it did not vary significantly from three and five irrigations. In the year 1943-44, there was a regular decline in ginning percentage as the quantity of water applied to the crop increased, 3 and 4 irrigations giving significantly higher values for this character than all the other treatments. The important conclusion, therefore, to be drawn from the combined results of the two years is that the ginning percentage is likely to increase under short water supply and decline with heavier quantities of water.

In order to find out the reasons for the increase of ginning percentage under reduced water supply and its decline with more liberal irrigations, an effort was made to split the ginning percentage into its important components, namely, seed weight, lint weight per seed, mean fibre length and mean fibre weight. The results of this analysis are given in Table II. It may be mentioned that, since all the constants other than the ginning percentage were determined from pooled produce of all the replications in the experiment, it was not possible to find out the true standard error of those constants. Consequently in Table II, no figures relating to critical differences have been given. This, however, does not reduce the value of the results, as the differential effect of various treatments is quite marked.

TABLE II

Mean values of ginning percentage and its components in the different number of irrigation experiments

Year	Characters	Number of irrigations					
		3	4	5	6	7	8
1942–43	Ginning percentage	33·60	33·97	33·72	33·06	33·36	33·36
	Seed Weight (mg.)	60·58	61·15	65·20	67·55	69·72	70·95
	Lint weight per seed (mg.)	30·34	31·16	33·33	33·35	34·80	35·51
	Fibre length (in.)	0·885	0·907	0·915	0·915	0·915	0·927
	Fibre weight per unit length (10^{-6} gm./cm.)	3·44	3·51	3·62	3·66	3·91	4·03
1943–44	Ginning percentage	31·25	30·64	30·18	30·00	29·70	29·43
	Seed weight (mg.)	65·40	65·90	69·60	70·00	73·33	74·50
	Lint weight per seed (mg.)	30·38	29·75	30·56	29·95	30·82	30·54
	Fibre length (in.)	0·88	0·91	0·91	0·91	0·92	0·93
	Fibre weight per unit length (10^{-6} gm./cm.)	3·54	3·77	3·78	3·79	3·83	3·86

It will be observed that the three characters, seed weight, fibre length and fibre weight, showed a progressive increase with an increase in the number of irrigations in both the years of the experiment, while the behaviour of lint weight per seed varied considerably within the two years. In the year 1942-43, this character, like seed weight, fibre length and fibre weight, maintained an upward trend with the increase in number of irrigations, while in the subsequent year (1943-44), it remained more or less at a constant level in all the irrigations. This observation is in harmony with that of Patel and Mankad [1923] who also observed the lint weight per seed to be a more variable character than seed weight. The ultimate effect of the increase in lint weight per seed during 1942-43 was to partially out-balance the reducing effect on ginning percentage of increased seed weight, so that the ginning percentage in case of lower to higher number of irrigations within this year varied only very slightly. On the other hand, the constancy of lint weight per seed in the year 1943-44 allowed increased seed weight to have its full play, with the result that the drop in ginning percentage due to increase in number of irrigations was more marked during this year than that in 1942-43.

Still another significant feature which requires special emphasis in connection with the above observations is that although fibre length and fibre weight under 8 irrigations were significantly higher than that of 3 irrigations during 1943-44, yet the lint weight per seed within these extremes of irrigations exhibited no appreciable differences. The logical conclusion of this is that fibre length and fibre weight form but very unimportant sub-components of lint weight per seed. In the determination of the latter character, the primary place, perhaps, goes to number of fibres per seed, as has also been inferred by Leake [1914], and it will be of great interest to study the behaviour of this component under differential irrigation treatments.

(B) *Effect of different frequencies and intensities of irrigation*

In experiments designed to study this aspect, a total of 20 acre-inches of water was applied to the Punjab-American variety L.S.S. in 3, 4, 6, 8 and 9 irrigations of equal intensities in the year 1942-43, and 3, 4, 5, 6 and 8 irrigations in the year 1943-44.

The analysis of variance revealed non-significant effect of treatments in the first year of the experiments and significant in the second year. The mean values of ginning percentage obtained in both these years along with critical differences and order of merit of different treatments is shown in Table III.

TABLE III

Mean values of ginning percentage under different intensities and frequencies of irrigation

Year	1	2	3	4	5	6	Critical difference (5 per cent)	Order of merit
	3 Irrigations each of 6·7 in.	4 Irrigations each of 5 in.	5 Irrigations each of 4 in.	6 Irrigations each of 3·3 in.	8 Irrigations each of 2·5 in.	9 Irrigations each of 2·2 in.		
1942–43	33·71	34·04	..	34·04	34·32	34·24	Non-significant	..
1943–44	28·47	28·34	28·60	28·56	30·21	..	±0·80	5, 3, 4, 1, 2

It will be seen from Table III that the values f ginning percentage remained at an almost nstant level in different treatments during 942-43. In 1943-44 also there were no differences the ginning percentage of the crop receiving 4, 5 and 6 irrigations of varying intensities, ıt, during this year, the application of 8 irriga- ons, each of 2·5 in. depth, produced significantly gher ginning percentage than all the other eatments.

C) *Effect of irrigating the crop on different dates*

In these experiments, a total of 20 in. water as applied in six irrigations as follows:

(*i*) Early start and early finish of irrigations, the ates of watering being 27/6, 21/7, 16/8, 5/9, /9 and 3/10. The depth of each irrigation as 3·33 in.

(*ii*) Medium start and medium finish, the dates f application of irrigations being 17/7, 16/8, 5/9, /9, 3/10 and 15/10, and the depth the same in (*i*).

(*iii*) Late start of irrigation and late finish, viz. 29/7, 31/8, 5/9, 1/10, 15/10 and 29/10. he depth of each irrigation in this case was also 33 in.

(*iv*) As in (*i*), but the earlier three irrigations ere lighter (2·5 in. each) and the later three eavy (4·17 in. each).

The experiments were performed only for one ar (1942-43) and the analysis of variance showed e effect of the treatments to be non-significant. he mean values of ginning percentage were 34·21, ·32, 34·26 and 34·11 for treatments (*i*), (*ii*), (*iii*) d (*iv*) respectively, from which it can be inferred at, so long as the total quantity of irrigation ater remained the same, starting the irrigations the crop early or delaying them by even one onth further, did not make any difference in e ginning percentage of varieties.

Another noteworthy observation in this experi- ent is that even treatment (*iv*), in which apart om time of irrigation, the intensity of waterings as also varied, did not exhibit any different nning percentage from other treatments. This bservation fully corroborates the conclusion set rth earlier in this paper that, within a fixed uantity of irrigation water, the variations in the tensity of irrigations have no appreciable effect n ginning percentage. The results also justify e conclusion that no increase in ginning per- ntage of varieties is likely to result from applica- on of lighter irrigations in the earlier stages of e growth of the crop, and heavier ones at the pposedly critical time of development of lint ores.

D) *Flat versus ridge irrigation*

Study of this irrigational phase was also done only for one year, viz. 1942-43. The sowing of the crop was done on flat, and the first irrigation was also applied in the ordinary way, but subsequently ridging was done in those plots where ridge irrigation was contemplated. The total quantity of water applied to the ridged and the flat plots was the same, viz. 16 in.

The analysis of variance revealed the effect of treatments to be non-significant, the mean values of ginning percentage under flat and ridge irrigations being 34·18 and 34·43 respectively. These results show that the method of application of water is not likely to make any difference in the ginning percentage of varieties, provided the total quantity of water remains the same.

(E) *Effect of fertilizers*

The data for this study was obtained from the manurial-cum-irrigational experiments of the Water Requirement of Crops Scheme, Risalewala, on L.S.S. The experiments were carried out only for one year (1943-44) and included the following treatments:

(*i*) *Manures.* No manure (M_0) and 40 (M_1), 80 (M_2) and 120 (M_3) lb. of nitrogen per acre from sodium nitrate.

(*ii*) *Irrigations.* Four irrigations (W_1), 6 irrigations (W_2) and 8 irrigations (W_3) with 3 in. depth of water in each case.

The analysis of variance showed significant effects of both fertilizers and irrigations individually, though their interaction was non-significant. The mean values of ginning percentage obtained in case of each of these treatments are given in Table IV.

TABLE IV

Mean values of ginning percentage in manurial-cum-irrigational experiment

Treatment	Doses of fertilizer and irrigation				Critical difference (5 per cent)	Order of merit
	M_0	$\frac{M_1}{W_1}$	$\frac{M_2}{W_2}$	$\frac{M_3}{W_3}$		
Manures	30·69	30·00	29·42	28·96	±0·34	M_0, M_1, M_2, M_3
Irrigations	..	30·11	29·67	29·52	±0·30	W_1, W_2, W_3

The results show that the ginning percentage declined progressively as the dose of the fertilizer increased. This tendency was so marked that all the doses varied significantly from each other. A similar decline also occurred with an increase in the number of irrigations, though from statistical stand-point only four irrigations gave significantly higher ginning percentage than the other two irrigational treatments, which did not vary *inter se*. These results fully confirm those given

earlier in this paper regarding the effect of varying quantities of water on ginning percentage.

Of still greater interest than the above result is the variation produced in different components of ginning percentage by different manurial treatments. The figures obtained with such treatments are presented in Table V.

TABLE V

Average value of ginning percentage and its components for different doses of sodium nitrate

Characters	Doses of fertilizer			
	M_0	M_1	M_2	M_3
Ginning percentage	30·68	29·99	29·42	28·96
Average seed weight (mg.)	71·28	73·58	75·11	78·46
Average lint weight per seed (mg.)	31·6	31·59	31·33	32·01
Mean fibre length (in.)	0·890	0·903	0·908	0·916
Mean fibre weight per unit length (10^{-6} gm./cm.)	3·46	3·64	3·81	3·98

The data show that, with an increase in the dose of the fertilizer, a progressive increase occurred in seed weight, fibre length and fibre weight. It would, however, be noticed that the increase in the latter two characters was very small indeed, so that their contribution towards increasing the average weight of lint per seed was almost negligible. The net result, therefore, was that the seed weight under different doses of fertilizer increased tremendously, while the lint weight per seed remained almost constant. Thus, the main factor causing reduction in the ginning percentage in this case was the seed weight.

(F) *Effect of sowing dates and spacings*

The data for this study were collected from two different complex experiments laid at the Cotton Research Farm, Risalewala, during 1943-44. The first of these included the following treatments :

(*i*) *Varieties.* 39 Mollisoni, L.S.S. and 199F.

(*ii*) *Spacings between rows.* 1 ft. (Sp_1), 2 ft. (Sp_2), 3 ft. (Sp_3).

(*iii*) *Sowing dates.* 6/5 (SD_1), 28/5 (SD_2), 19/6 (SD_3).

The analysis of variance in these experiments showed the effect of sowing dates to be highly significant in American varieties (L.S.S. and 199F) but not in *desi* (39 Mollisoni). In contrast to this, the effect of spacings was uniformly significant in both *desi* and American varieties. The interaction between spacings and sowing dates, however, was non-significant in all the types.

The mean values of ginning percentage with different sowing dates and spacings in each of the three varieties are given in Tables VI and VII respectively.

TABLE VI

Mean values of ginning percentage with different sowing dates

Varieties	SD_1	SD_2	SD_3	Critical difference (5 per cent)	Order of merit
39 Mollisoni	33·57	34·00	33·66	N.S.	
L.S.S.	32·23	31·08	28·98	±0·876	SD_1, SD_2, SD_3
199F	37·92	36·64	36·91	±0·627	SD_1, SD_3, SD_2

TABLE VII

Mean values of ginning percentage with different spacings

Varieties	Sp_1	Sp_2	Sp_3	Critical difference (5 per cent)	Order of merit
39 Mollisoni	34·90	33·74	32·74	±0·60	Sp_1, Sp_2, Sp_3
L.S.S.	31·27	30·71	30·29	±0·699	Sp_1, Sp_2, Sp_3
199F	37·63	37·30	36·54	±0·519	Sp_1, Sp_2, Sp_3

The data presented in Table VI show that, in the American variety L.S.S. the results with all the sowing dates varied significantly from one another, first sowing date giving the highest value and third the least. In case of variety *199F*, first sowing date gave significantly better ginning percentage than the second and the third, but the difference between the latter two was non-significant.

As regards spacings, its effect was most marked in the *desi* variety, *39 Mollisoni*, where the results with each of the spacings tried varied significantly from one another, highest ginning percentage having resulted from 1 ft. spacing and the least from 3 ft. spacing between rows of the crop. In both the American varieties also, the effect of spacings was similar to that in *39 Mollisoni*, the closest spacing yielding highest value of ginning percentage and the widest the least as will be noticed from Table VII, but the differences were not as distinctly significant as in the case of *Mollisoni*.

The second set of experiments, from which data for studying the effect of spacing and sowing dates on ginning percentage were obtained, included the following treatments :

(*ii*) *Spacings between rows and plants* :
1 ft.×1 ft. (Sp_1) ; 2 ft.×1 ft. (Sp_2) ;
3 ft.×1 ft. (Sp_3) ; 2 ft.×2 ft. (Sp_4) ;
3 ft.×2 ft. (Sp_5).

(*ii*) *Sowing dates.* 16/5 (SD_1), 4/6 (SD_2), /6 (SD_3).

Only one variety was used in the experiment, . the Punjab-American cotton, 4F.

The mean values of ginning percentage obtained each of the above mentioned treatments are ven below :

cings	Sp_1	Sp_2	Sp_3	Sp_4	Sp_5	Critical difference
	33·96	33·40	33·12	32·49	32·07	±0·09

ving tes	SD_1	SD_2	SD_3	Critical difference
	33·92	32·70	32·40	±0·23

These results are in close conformity with those previous experiments and show conclusively that e ginning percentage of the variety 4F was pressed as sowings were delayed and also as the acings between rows and plants became wider.

Discussion

The bearing of some of the important agronomic eatments on ginning outturn of a few Punjab si and American varieties has been given in the regoing pages. The results show that flat versus dge irrigationdid not influence ginning percentage any appreciable extent. Similarly, in the periment designed to find out the effect of igating the crop on different dates, no significant ferences were observed in the ginning percentage varieties due to types of irrigation employed. ne results of intensities and frequencies of irrigaon experiments, however, reveal that 20 acre-in. water, when applied in 8 equal irrigations gave gnificantly higher ginning percentage in 1943-44, t that the same treatment failed to produce any arked effect on ginning outturn in 1942-43. nce the other frequencies and intensities of igation in both the years did not show any gnificant differences *inter se*, and since even 8 igations gave very inconsistent results in the o years, it is safe to conclude that the frequency intensity of irrigation also has no effect on nning percentage, so long as the total quantity irrigation water applied to the crop remains the ne.

In contrast, however, to the above treatments, e application of different quantities of water to e variety L.S.S. has given consistent results both the years of experimentation, the ginning rcentage in general increasing under short water pply and vice versa. Thus, from a practical stand point, it is the total quantity of water applied to the crop which is really effective in modifying the ginning percentage of varieties and not its intensity, or date and method of application. The relevent question, however, to be asked in this connection is whether the application of lower quantities of water could be advocated as a method of obtaining higher ginning percentage of cotton varieties ? The answer to this question can be given by considering the variations that are produced in different components of ginning percentage as a result of the application of different quantities of water. The present investigation has shown that the seed weight goes down with the reduction in the quantity of irrigation water, which means that a greater percentage of immature seeds is likely to result from such a treatment. Since such undeveloped seeds cannot be expected to bear lint of proper maturity and length, it is doubtful if reduction in the quantity of irrigation water will ever be a practical proposition for achieving higher ginning percentage. This conclusion is supported by the results of Sturkie [1934], who found an increase in ginning percentage with decrease in water supply and concluded that this increase was due to a greater decrease in seed weight than to any corresponding decrease in lint weight per seed.

The effect of the addition of increasing doses of inorganic manure, sodium nitrate, has also been to depress ginning percentage. This result is in agreement with that of Brown [1928] who states that cotton grown on rich lands or land with liberal application of sodium nitrate has lower ginning percentage than cotton grown on less fertile soils. The analysis of ginning percentage into its constitutent components in the manurial experiment further reveals that the depression in this character as a result of increasing dose of the fertilizer is due mainly to increase in seed weight, to which extent the addition of inorganic manures is desirable from a practical stand point for reasons similar to those given for application of heavier doses of irrigation water.

As regards the effect of spacings on ginning percentage, it is evident from the results that closer spacing (i.e. 1 ft.×1 ft.) led to significantly higher values of this character than the medium or wider spacings. This is probably due to the greater number of plants per unit area in closer spacings and thus to smaller amount of nutrient matter available to each plant for normal development of seed and lint. It would be of great interest to study the variation in seed weight and lint weight per seed of plants grown with different spacings to throw further light on this aspect of the problem. The work of Balls [1912] reveals that lower ginning outturn with wider spacings

is due to greater increase in seed weight than to any corresponding increase in lint weight per seed.

The effect of sowing dates on ginning outturn has also been quite marked in that the first sowing date has given higher ginning outturn than the other sowing dates in case of Punjab-American varieties only. Although it has not been found by actual studies how this variation in ginning outturn of different sowing dates is brought about, yet it is probable that seed weight is low in the crop yielded by the first sowing date, which would naturally push up its ginning outturn. But, as has been mentioned above a low seed weight is likely to be accompanied by lint of poor quality, it may not be desirable from a practical stand point to advocate early sowings of cotton. Further justification for this conclusion is afforded by the fact that the yield and quality of the crop in later sowings show a marked improvement over the early sowings in the Punjab, as has been established by the work of Trought [1930] and Dastur and Mukhtar Singh [1942].

The above discussion amplifies the fact that the scope for achieving higher ginning percentage of varieties, at least in the Punjab, by effecting changes in the commonly used agronomic treatments is very meagre indeed. The limit to such a possibility is set by the seed weight, which has been seen to be affected by these agronomic treatments to a much greater degree than the lint weight per seed. This fact doubly increases the responsibility of the cotton breeder on whom the task of maintaining ginning percentage, in the new varieties evolved by him, at the highest possible pitch becomes incumbent, so that those varieties even after being subjected to liberal water supply, manuring, late sowings, etc. which are essential for obtaining proper yield and quality, can still give a ginning percentage not below the economic level.

Summary

The variations produced in the ginning percentage of a few Punjab-American and *desi* varieties of cotton by some of the important agronomic treatments have been studied.

By application of 3 to 8 irrigations, each of 3 inches depth, the ginning percentage generally declined as the quantity of water applied to the crop increased. This reduction is mainly the result of increase in seed weight.

The application of 20 in. water in 3 to 9 irrigations of different intensities failed to affect ginning outturn appreciably during 1942-43, but in the succeeding year 8 irrigations, when applied in doses of 2½ in. each, gave significantly higher ginning percentage than all the other intensities.

So long as the total quantity of water applied to the crop remained the same, starting irrigations early or delaying them by even one month did not make any difference in the ginning percentage.

Application of lighter irrigations in the early stages of growth and heavier ones near the flowering and fruiting time of the crop produced no change in ginning percentage.

There was no difference in the ginning percentage of crop grown under flat or ridge irrigation.

The effect of addition of increasing doses of sodium nitrate was to progressively depress the ginning percentage mainly as a result of increase in seed weight.

Sowing dates and spacings affected the ginning percentage of varieties significantly, higher values of this character having been obtained with early sowings and closer spacings.

The possibility of achieving higher ginning percentage of varieties by effecting changes in the commonly used agronomic treatments in the Punjab has been discussed.

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INVESTIGATIONS ON SOME FUNDAMENTAL ASPECTS OF CITRUS PROPAGATION IN ASSAM

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The genus *Citrus* comprises a wide range of fruits which are prominent in both the internal and external trade of Assam. Some of the species, namely the *Khasi* orange (*C. chrysocarpa* Lush.), lemon (*C. limonia* Osbeck) and lime (*C. aurantifolia* Swingle) occupy a total of about 25,000 acres and are commercially the most important. Besides, there are other species like shaddock (*C. maxima* Merril), citron (*C. medica* Linn.), *C. macroptera* Mont. and *C. limettioides* Tanaka, to name a few, which though commercially unimportant, are nevertheless grown in many a homestead for family needs. Notwithstanding the antiquity and the economic importance of citrus cultivation, the province had, hitherto, taken no serious interest in guiding the industry on a sound scientific basis. Left entirely to private initiative and enterprise it began to develop by feeling its way according to its own light. Technical methods so widely and advantageously adopted in other parts of the world did not seem to have much influence here. Propagation, as in nature, was carried on almost entirely through seeds. The only man-made device was 'gootee' or 'marcotte' a process which seems to have been independently developed and employed for the propagation of those varieties of limes and lemons which Nature most unkindly did not provide with numerous seeds for easy and quick multiplication.

With the inauguration of the citrus research at Burnihat, Assam, under the joint auspices of the Provincial Government and the Imperial Council of Agricultural Research, India, attempts are now being made to make up for the time lost and evolve techniques of propagation and cultivation for developing the industry on a sound and a rational basis. This paper deals with some of the fundamental aspects of propagation in the nursery.

Polyembryony in different citrus varieties

Polyembryony or the presence of more than one embryo within a seed, has long been known to occur in certain varieties of citrus [Leeuwenhoek, 1719; Frost, 1926; Toxopeus, 1931; Webber, 1937 and Naik, 1939]. The importance of this phenomenon in a nursery lies in the fact that once the gametic seedlings which are generally weak growers are eliminated the remaining seedlings of apogamic origin conform to the parental type and thus it becomes possible to establish clonal lines for a variety in a most natural way without taking recourse to any artificial means. With a view to observing to what extent this phenomenon occurs in some of the important indigenous citrus varieties, a preliminary study was carried out in the seed-bed, counting separately the seeds producing one seedling each and those producing more than one.

Table I

Percentage of polyembryonic seeds in different citrus varieties detected at germination

Varieties	Number of germinated seeds examined	Total number of seeds each producing			Percent of seeds producing more than one seedling
		Two seedlings	Three seedlings	Four seedlings	
Muri Tenga (*C. limettioides* Tanaka)	380	138	..	2	36·84
Soh Myndong (*C. limonia* Osbeck)	146	34	2	..	24·64
Nemu Tenga (*C. limonia* Osbeck)	200	66	1	..	33·50
Kata Jamir (*C. limonia* Osbeck)	252	79	4	..	32·93
Karun Jamir (*C. aurantium* Linn.)	328	44	..	..	13·41
Khasi orange (*C. chrysocarba* Lushington)	469	122	5	..	27·08
Ada Jamir (*C. sp.*)	160	24	..	..	15·00
Rabab Tenga (*C. maxima* Merril)	496	..	..	..	*nil*
Jora Tenga (*C. medica* Linn.)	130	..	..	..	*nil*

The foregoing figures are at best a rough indication of the extent of polyembryony present in these varieties, for it is not sure that all seeds producing one seedling each are monoembryonic. Polyembryonic seeds of citrus usually seem to produce not more than two seedlings each. Further

the total absence of polyembryony in shaddocks and citrons tends to show that the phenomenon is not common in all the citrus species. This is in conformity with the observations of Naik [1940]. The extent of polyembryony in the Khasi orange (*C. chrysocarpa* Lush.) is about 27 per cent and this probably explains why in spite of continuous natural cross pollination, there is such a comparative great uniformity of seedling trees as is found in the province.

Germination of orange seeds (*C. chrysocarpa* Lushington) at different stages of maturity of fruits

As has been stated before, the propagation of loose-skinned oranges in Assam is carried on almost exclusively through seeds. An experiment was therefore conducted with the object of ascertaining the stage of maturity of fruits at which the maximum germination may be obtained. Twentyfive fruits were picked from a particular orange tree once every fortnight and 200 well-developed seeds selected from the fruits of each lot were put, immediately after extraction, in a sandbed for germination.

Table II

Percentage of germination of seeds at different stages of maturity of fruits, the percentage of polyembryonic seeds among them and the time taken for germination to start and its completion

Dates of sowing	Number of seeds germinated	Time for commencement of germination in days	Time for complete germination	Percentage of germination	Number of Polyembryonic seeds detected	Percentage of Polyembryonic seeds detected
15.9.41	95	26	42	47·5	20	21·05
1.10.41	82	31	47	41	19	23·2
15.10.41	128	26	65	64	30	23·4
1.11.41	175	33	60	87·5	36	20·6
15.11.41	190	31	65	95	39	20·5
1.12.41	186	30	67	93	41	22·0
15.12.41	190	31	65	95	50	26·3
1.1.42	174	35	68	87	37	21·2
15.1.42	166	37	72	83	37	22·2
1.2.42	162	45	76	81	43	26·5

The mean outside maximum temperature from September, 1941, to May, 1942, month by month was 89·3°, 86·5°, 77·2°, 74·2°, 71·0°, 76·5°, 81·8°, 85·5° and 87·2°F. respectively. It will be seen that inspite of a gradual rise in temperature from February onwards, the time required for germination for the connected sowings has increased and the percentage of germination for the same has decreased to a certain extent, though it is known that rise in temperature hastens germination. So the differences in the percentage of germination and the time required for germination in this case are probably due to differences in maturity of fruits. The results indicate that the seeds of mature fruits have a better viability than those of less mature ones. Over-ripening of fruits appears to lower the germinating capacity of seeds to a small extent and prolongs the period of germination quite considerably. The interval between the time of sowing and the commencement of germination seems to increase with the advancing maturity of fruits.

Immaturity of seeds has probably a more detrimental effect on the gametic rather than on the nucellar embryo as is evident from the fact that irrespective of the stages of maturity of fruits, the percentage of germination of polyembryonic seeds is fairly constant ranging from 20·5 to 26·5. Perhaps the nucellar embryos develop sooner than the gametic ones in this variety.

Effect of sunning on the germinating capacity of orange seeds (*C. chrysocarpa* Lushington)

The popular belief among the growers is that to ensure satisfactory germination the seeds of all kinds should be as thoroughly dried as possible by subjecting them to direct sunshine for protracted periods. In order to see how far this rule is applicable to the orange a small quantity of orange seeds from mature and healthy fruits from a single tree was subjected to different periods of sunning from zero to forty hours and tested for germination in a sandbed.

Table III

Percentage of germination of orange seeds subjected to different periods of sunning

Date of sowing	Duration of sunning in hours	Number of seeds sown	Number of seeds germinated	Percentage of germination	Time taken for commencement of germination in days
26.1.42	0	200	192	96	33
26.1.42	4	„	162	81	33
27.1.42	8	„	102	51	36
28.1.42	12	„	62	31	38
29.1.42	16	„	12	6	41
30.1.42	20	„	14	7	39
31.1.42	24	„	6	3	54
1.2.42	28	„	2	1	49
2.2.42	32	„	2	1	50
3.2.42	36	„	*nil*	*nil*	..
4.2.42	40	„	*nil*	*nil*	..

The foregoing results indicate that the erminating capacity of orange seeds progressively leteriorates with increased doses of sunning, that he fresh seeds ensure the highest germination nd that in no case should the seeds be exposed o direct sun for more than four hours. The ime taken for commencement of germination eems to increase with the increased period of unning.

Duration of the viability of citrus seeds

The object of the experiment was to find out ow long the viability of citrus seeds remains nimpaired if these are kept in an airtight ontainer. The significance of this experiment lies n the fact that sometimes it becomes essential to send the seeds to a distant place or to preserve them for deferred sowing. Seeds of seven varieties of citrus representing three grades, viz. big, medium, and small, were selected for the experiment. The seeds of different varieties were extracted from well-matured fruits on 29 December, 1943, and dried in shade for three days. Four hundred seeds of each variety mixed with charcoal powder were kept separately in a desiccator for two and a half months after which one hundred seeds of each variety were put in a sandbed for germination. The remaining seeds were sown at intervals of seven days from the date of first sowing.

The results tend to show that the big sized seeds retain viability for a longer period than the small ones and that there is a gradual fall in vitality of stored seeds irrespective of size.

Table IV

Percentage of germination, size of seeds, and minimum time required for germination to commence

Name of variety of seeds	Number of seeds sown	Average size of seeds (length × breadth)	Date of sowing	Number germinated or per cent of germination	Time interval for germination to start (in days)
Rabab Tenga (*C. maxima* Merril)	100	1·94 cm. × 1·12 cm. = 2·17 sq. cm.	20.3.44	78	44
	,,		27.3.44	64	39
	,,		3.4.44	30	40
	,,		10.4.44	15	31
Karun Jamir (*C. aurantium* Linn.)	100	1·82 cm. × 0·82 cm. = 1·49 sq. cm.	20.3.44	56	42
	,,		27.3.44	40	38
	,,		3.4.44	26	43
	,,		10.4.44	10	38
Muri Tenga (*C. limettioides* Tanaka)	100	1·52 cm. × 0·80 cm. = 1·02 sq. cm.	20.3.44	48	41
	,,		27.3.44	32	38
	,,		3.4.44	14	42
	,,		10.4.44	*nil*	..
Jora Tenga (*C. medica* Linn.)	100	1·32 cm. × 0·68 cm. = 0·89 sq. cm.	20.3.44	52	39
	,,		27.3.44	46	40
	,,		3.4.44	32	34
	,,		10.4.44	8	38
Soh Sarkar (*C. Karna* Raf.)	100	1·14 cm. × 0·72 cm. = 0·82 sq. cm.	20.3.44	46	38
	,,		27.3.44	36	38
	,,		3.4.44	28	37
	,,		10.4.44	*nil*	*nil*
Tulia Tenga (*C. limonia* Osbeck)	100	1·20 cm. × 0·59 cm. = 0·60 sq. cm.	20.3.44	32	40
	,,		27.3.44	34	38
	,,		3.4.44	18	36
	,,		10.4.44	14	38
Soh Myndong (*C. limomia* Osbeck)	100	1·24 cm. × 0·45 cm. = 0·65 sq. cm.	20.3.44	42	42
	,,		27.3.44	36	42
	,,		3.4.44	33	36
	,,		10.4.44	damaged	*nil*

Klimenko [1937] has also observed that the vitality of citrus seeds progressively decreases with increased storage.

Propagation of plants by root-cuttings in the open bed

Investigation into the possibilities of raising plants of different citrus varieties from root cuttings, planted in the open-bed, was made mainly in relation to raising standardized clonal materials. Cuttings of two sizes, viz. 4-6 mm. and 2-3 mm. thickness of 8 in. length, obtained from 2-3 year old trees from 6-8 in. below ground level were planted in a sandbed during July, i.e. when the monsoon had well set in.

Table V

Percentage of success obtained in propagating plants from root cuttings of different citrus varieties

Variety	Number of root piece planted	Diameter of roots in mm.	Number of plants propagated	Percentage of success
Jora Tenga	50	4–6	34	68
(*C. medica* Linn.)	,,	2–3	28	56
Soh Myndong	,,	4–6	27	54
(*C. limonia* Osbeck)	,,	2–3	6	12
Muri Tenga	,,	4–6	23	46
(*C. limettioides* Tanaka)	,,	2–3	11	22
Khasi orange	,,	4–6	..	..
(*C. chrysocarpa* Lushington)	,,	2–3	..	..
Karun Jamir	,,	4–6	..	..
(*C. aurantium* Linn.)	,,	2–3	..	..
Rabab Tenga	,,	4–6	..	..
(*C. maxima* Merril)	,,	2–3	..	..
Satkora	,,	4–6	..	..
(*C. macroptera* Mont.)	,,	2–3	..	..

Observations indicate that only citrons and lemons may be propagated by this method with appreciable success. The degree of success obtained with rough lemon shows that this method may be profitably employed for multiplication of this important stock type so commonly used for budding different scion varieties. Roots of shaddocks, the Seville orange, Mandarin orange and *C. macroptera* fail to strike out any shoot when planted in the open bed. General observations, however, indicate that if the stock is removed and the roots are kept slightly exposed *in situ* or if the roots are severed from the mother plant and the cut ends are slightly raised above ground and left, then varieties like *C. chrysocarpa* and *C. macroptera*, which otherwise do not sprout from planted root cuttings, do form shoots from the exposed root-ends. Roots of 4-6 mm. thickness seem to give a higher percentage of success than those of lesser thickness. This is because root bits of small girth dry up quickly and perish. Halma [1931] and Hunter [1932] also carried out similar investigations on root cuttings without any striking success.

Propagation from stem cuttings treated with 'Hortomone A'

Of all the different citrus varieties only citrons and lemons may be ordinarily propagated from stem cuttings. An investigation was, therefore, undertaken to ascertain whether it is possible to accelerate root formations in citrons and lemons and induce rootings in other varieties by treating their respective stem cuttings with 'Hortomone A', a synthetic plant hormone or auxin patented by the Imperial Chemical Industries Ltd.

Stem cuttings of seven varieties of citrus were obtained from approximately one and a half year old branches of a particular tree of each. The cuttings were 9 in. in length and 8 to 10 mm. in diameter with a terminal flush of 3 to 4 mature leaves in each [Halma 1931]. Thirty cuttings of each of the varieties cut just below a node and tied in separate bundles, were kept with the lower ends, in a solution of 'Hortomone A' prepared in the proportion of half an ounce to a gallon of water for 16 hours after which the treated cuttings were removed and rinsed thoroughly in water. Thirty cuttings of each variety were left untreated to serve as a control.

The treated cuttings together with a set of controls for each were planted in a slanting manner, two feet apart in a bed of soil mixed with well-rotted cowdung and leaf mould. The planting was done on 6 May 1943, and within three weeks the treated cuttings in most cases began to produce new shoots. The production of new growths was found to vary within the varieties. The cuttings were excavated at the end of three months and the soils attached to the roots were washed away carefully using a pressure sprayer.

TABLE VI

Percentage of survival, mean length of roots, total weights of roots and shoots and ratio of shoot to root of the treated and untreated stem cuttings

me of variety	Number of cuttings employed in each treament	Number of survival		Per cent of survival		Mean length of root in cm.		Total weight of roots in gm.		Total weight of shoots in gm.		Ratio of $\frac{\text{shoot}}{\text{Root}}$	
		Treated	Untreated control	Treated	Untreated control	Treated	Untreated control	Treated	Untreated control	Treated	Untreated control	Treated	Untreated control
Tenga (*C. medica* Linn.)	30	28	26	93·3	86·6	13·3	10·3	121·18	45·08	381·6	196·2	3·14	432
Jamir (*C. limonia* Osbeck)	,,	28	24	93·3	80·0	10·1	7·4	56·54	10·34	138·14	42·90	2·44	4·14
Myndong (*limonia* Osbeck)	,,	28	26	93·3	86·6	8·1	4·1	20·54	4·54	46·54	20·84	2·26	8·59
Tenga (*limettioides* Tanaka)	,,	16	12	53·3	40·0	5·5	2·3	4·70	1·88	27·22	9·58	5·79	5·09
n Jamir (*aurantium* Linn.)	,,	18	14	60·0	46·6	3·1	1·06	0·88	0·08	6·40	0·74	7·27	9·25
ab Tenga (*maxima* Merril)	,,	20	14	66·6	46·6	2·9	0·98	1·64	0·06	6·90	0·64	4·21	10·66
ora (*macroptera* Mont.)	,,	18	14	60·0	46·6	0·90	0·47	0·10	Trace	0·20	Trace	2·00	..
si orange (*chrysocarpa* Lush.)	,,	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*

From the above results it may be stated that eatment with 'Hortomone A' causes a higher rcentage of survival in cuttings of those varieties ich are normally amenable to propagation from ttings, but it fails to induce rooting in one which dinarily does not root from cuttings. The emical, however, seems to have some influence in celerating both root and shoot formations.

OPAGATION OF CITRUS VARIETIES BY 'GOOTEE' OR 'MARCOTTE'

As a method of propagation 'gootee' is probably e most antique and universal in use. All the rus varieties are amenable to multiplication by s method. And yet for successful nursery practice there is the necessity for collecting informations as to the minimum time required for the formation of roots and the possible percentage of success attainable in different citrus varieties.

Ten varieties of citrus were selected for the study and the 'gootee' operation was carried out in the usual manner [Burns, 1930] during July, i.e. in the height of the monsoon. To find out the actual time of root formations occasional examination was made into the 'gootee' by splitting open the upper sides of the ball of rooting compost. All the varieties were found to form roots within two months and the total rainfall during the corresponding period, i.e. July and August, was 22·60 in. spread over 39 days.

TABLE VII

Range of time required for the formation of roots in the 'gootee' and the percentage of success in different varieties of citrus

Varieties	Number of 'gootee' operated	Number of success	Percentage of success	Range of time required for root formation (in days)
a Tenga (*C. medica* Linn.)	20	20	100	20–25
am lemon (*C. limonia* Osbeck)	20	20	100	22–26
Myndong (*C. limonia* Osbeck)	20	20	100	31–40
ri Tenga (*C. limettioides* Tanaka)	20	20	100	32–40
kora (*C. macroptera* Mont.)	20	20	100	36–42
sambique (*C. sinensis* Osbeck)	20	20	100	38–44
encia orange (*C. sinensis* Osbeck)	20	14	70	44–52
run Jamir (*C. aurantium* Linn.)	20	16	80	40–48
asi orange (*C. chrysocarpa* Lushington) ..	20	18	90	45–55
ape Fruit (*C. paradisi* Macf.)	20	16	80	48–54

It may be seen from the foregoing results that all the ten varieties under trial may be successfully propagated by this method if the operation is carried out in the rainy season. There seems to be a distinct varietal difference in the time taken for the formation of roots varying as widely as from 20 to 55 days. Citrons, lemons, *C. macroptera* and *C. limettioides* strike out roots much more quickly than the tight-skinned, loose-skinned, Seville oranges and grapefruits.

Propagation by bark-grafting

In propagating citrus varieties on different rootstocks, budding is by far the commonest and easiest method. But the percentage of success attained by budding during June, July and August is somewhat low due to the prevalence of continuous wet weather and it is in this period that bark-grafting may be adopted in the nursery with advantage. The operation is akin to crown grafting with the scion-stick inserted into a sli prepared between the bark and wood of the stocl and may be conveniently employed in any stocl in which the bark will slip. The small stock plant with a diameter of 0·7 cm. give equally good results as those of a diameter of 2 cm. This method is particularly suitable in inducing ar earlier feathering in grapefruits which wher budded take an unusually long period ranging from 3-6 months for bud-break. The success or failure of bark-grafting, however, depends very much on the prevailing atmospheric condition. If the operation is followed immediately afterwards by many rainy days the success is assured, but on the other hand if a dry spell lasting even for 4 days intervenes immediately after the operation the percentage of success is much less.

Table VIII

Effect of dry and wet weather on the success of bark-grafting

Dates of operation	Number of plants grafted	Number of sunny days in the first week after operation	Number of rainy days in the first fortnight after operation	Number of successful plants	Percentage of success	Mean number of days for bud-break
11 July 1940 ..	14	1	14	12	87	38
16 July 1940 ..	20	.	15	16	80	34
29 July 1940 ..	15	4	10	8	53	30
10 August 1940 ..	15	2	13	13	86·6	42
22 August 1940 ..	20	7	7	7	35	48
14 September 1940 ..	30	7	7	..	..	..
16 October 1940 ..	12	7	..	..	..	..
18 November 1940 ..	14	7	..	..	..	..

Note :—Scion—Khasi orange (*C. chrysocarpa* Lushington)
Stock—Soh Myndong (*C. limonia* Osbeck)

The foregoing results clearly indicate that the optimum season for bark-grafting is during July and August, i.e. during the rains. But even during this period the success depends on the continuity of wet weather. The low percentage of success for the operations carried out on 29 July and 22 August 1940, was due to the fact that in each case the operation was followed immediately afterwards by 4 and 7 sunny days respectively even though there were 10 and 7 rainy days respectively in the later part. The total failure of bark-grafting during the winter months may be attributed to the absence of an active growing condition in the plants and to the attendant low humidity of the atmosphere.

Propagation by budding

Of the different methods of vegetative propagation employed in citrus, budding is by far the most efficient and universally practised. There is however, a divergence of opinion among the horticulturists about the details of the technique. The inverted 'T' with a minute piece of wood attached to the bud-shield is advocated by some [Hume, 1941 ; Wickson, 1926 ; Camp, 1931 ; and Naik, 1939] while the removal of the wood from the bud-shield is suggested by others [Hall and Crane, 1933]. In South Africa the question of the retention or removal of wood is considered to be a matter of individual preference [Powell, 1930]. A trial was therefore conducted to find out the relative success in bud-take and joint formation by different methods of budding. The operation was carried out by one single budder using scions of Khasi orange (*C. chrysocarpa* Lushington) on root-stocks of Kata Jamir (*C. limonia* Osbeck).

TABLE IX

Percentage of bud-take and the period of bud-break by different methods of budding

Method of budding	Number of plants budded	Mean height in cm. of root-stock	S.E.	Mean stem diameter in mm. of rootstock	S.E.	Number of success-ful bud-take	Percen-tage of bud-take	Mean period of bud-break in days	S.E.
A. Inverted 'T' with wood	25	65·24	1·28	9·48	0·26	22	88	54·52	1·23
B. Inverted 'T' without wood	25	67·24	0·93	9·12	0·27	14	56	56·36	1·56
C. Normal 'T' with wood	25	69·76	1·64	9·40	0·18	18	72	53·61	1·49
D. Normal 'T' without wood	25	69·44	2·59	9·36	0·26	15	60	54·40	1·54

Rootstock— Kata Jamir (*C. limonia* Osbeck)
Scion— Khasi orange (*C. chroysocarpa* Lushington)
Age of stock plants at budding—11 months
Dates of budding—14.1.42 and 15.1.42

NOTE :—When the various treatments are compared at 5 per cent level of significance, the relation with respect to the various characters are as follows :

Height of stock seedlings— A. B. C. D.
Stem diameter of stock— A. B. C. D
Period of bud-break— B. A. D. C.

Of the four methods of shield-budding tested both the inverted 'T' and normal 'T' with the wood attached to the bud-shield have given a high percentage of success, viz. 80 per cent and 72 per cent respectively. The former method is customarily practised in this nursery and the slightly higher percentage of bud-take than with the latter may partly be due to a greater skill and dexterity of hand achieved by constant practice. The low bud-take both with normal and inverted 'T' with the wood removed, viz. 60 per cent and 56 per cent respectively is probably primarily due to knife injury unconsciously inflicted on the bud-shield while removing the wood. In any case the removal of the wood does not seem to be justified as the percentage of bud-take is lower and as it unnecessarily taxes the patience, skill and the time of the budder. Besides, the difference of presence or absence of wood does not seem to have any influence either on the period of bud-break or on the quality of bud-joint. True, the retention of an unnecessarily big or rough wood-slice may give rise to a swollen joint [Mendel, 1936] but this only discredits the budder and not the method.

INFLUENCE OF SEASON ON THE SUCCESS OF BUDDING

Knowledge regarding the optimum season for budding is essential for successful nursery work. A trial was, therefore, conducted by carrying out budding on a lemon rootstock with bud-wood obtained from a selected orange tree once every month to ascertain the effect of season. All the operations in different months were done by a single budder. In a protracted trial of this nature spread over twelve months of the year the influence of season, however, gets partially masked by the varying age of the stock materials. In the trial conducted, the age of the stock plants for October operations was only nine months whereas the same for September operation in the following year was about 20 months. The old plants were kept in a workable condition by cutting back the main stem and allowing a shoot to grow on which the subsequent bud-insertions were carried out. This could not be helped as it was not found practicable to maintain a constant age of stock materials by carrying out a monthly sowing primarily because of the short-lived viability of seeds and secondly because of the differential influence of seasons themselves on the growth of the plants.

TABLE X

Success of budding in different months of the year with corresponding period of bud-break

Months	Number of plants budded	Number of success-ful bud-take	Percentage of success	Mean period of bud-break in days
January ..	25	25	100	55·96
February ..	,,	21	84	49·90
March ..	,,	12	48	54·30
April ..	,,	18	72	59·20
May ..	,,	17	68	49·41
June ..	,,	15	60	62·20
July ..	,,	15	60	62·13
August ..	,,	18	72	56·56
September ..	,,	20	80	49·90
October ..	,,	14	56	60·20
November ..	,,	25	100	57·60
December ..	,,	25	100	59·50

Rootstock—Kata Jamir (*C. limonia* Osbeck)
Scion —Khasi orange (*C. chrysocarpa* Lushington)
Seedlings were budded on the 15th of every month

From the above data it may be seen that budding may be carried out almost throughout the year with different degrees of success. The period from November to January seems to be the optimum season and September and February seem to be the next best. Protracted dry and wet weather during the summer months are unfavourable for budding. Under wet conditions fairly good results may be obtained by employing paraffin coated wrappers which prevent the rain water from getting into the slit, but during dry weather no protection can be rendered to a freshly inserted bud which frequently dries and shrivels up. In Madras, July to September is considered to be the optimum season while October to January is considered to be the next best [Naik, 1939]. The position in Assam seems to be almost the reverse. The period of bud-break for the Khasi orange varies from 49 to 62 days and does not seem to show any distinct seasonal variation. Even if there be any seasonable influence it probably gets covered up by the variable character of bud materials as regards the stage of dormancy. It is a matter of experience that the majority of orange buds obtained from the fruiting branch of a seedling orange tree tend to be partially blind and vigilant care has to be exercised in selecting active buds. In a nursery plot for mass propagation when the selection of buds was left to the discretion of a *mali* it was found that out of 48 successful buds worked on rough lemon rootstocks only 11 burst out within 60 days and the reminder took anything between 100 and 150 days.

Effect of lopping the root-stock at the time of budding and lopping it after the budling has attained a a height of 3 in.

Information as to when the stock plants should be lopped off so as to secure the maximum growth of the budling is indeed important. A trial was, therefore, conducted with two groups of Kata Jamir seedlings (*C. limonia* Osbeck) identical in age and origin. The mean height and mean diameter of one group of seedlings recorded just before bud-insertion were 64·03 cm. and 11·59 mm. with a SE of 1·09 and 0·24 respectively. The mean height and the mean diameter of the other group of seedlings recorded on the same day were 65·47 cm. and 11·59 mm. with SE of 1·25 and 0·24 respectively showing that the stock materials for both the groups were statistically identical at a 5 per cent level of significance. Plants of both the groups were budded on 6, January 1942, with budwood obtained from a selected Khasi orange (*C. chrysocarpa* Lushington) tree by the same operator. Immediately after budding the plants of one group were lopped off at a height of 6 in. above the point of union and the plants of the other group were allowed to grow unlopped till the budlings in each case had attained an approximate height of 3 in. The cut at a height of 6 in. was settled with the idea of cutting back the stub to the bud in a progressive manner, instead of in one single cut, as has been advised by Baily [1920], Davis [1917] and Powell [1930]. The extension growth of the individual budlings was recorded on 5, May 1942, i.e. after an interval of four months from the date of budding.

Table XI

Effect of lopping the root-stock at the time of budding on the percentage of success, period of bud-break and extension growth

Treatment	Number of plants budded	Number of success	Percentage of success	Mean period of budbreak in days	S.E.	Mean extension growth in cm.	S.E.
A. Stock lopped at budding	32	25	78·12	47·24	1·09	36·16	1·14
B. Stock lopped after budling attained 3 in. in height	32	27	84·37	58·30	1·26	47·26	1·57

Note— When these treatments are compared at 5 per cent level of significance the conclusion is as follows:
Period of bud-break— B is significantly greater than A
Mean extension growth—B is significantly greater than A

The above results tend to show that the lopping of the stock plants at the time of budding may lower the percentage of bud-take slightly and induce an earlier bud-break by about 11 days. But notwithstanding the advantage of an earlier bud-break the amount of extension growth of the budlings, attained in a period of four months from the date of budding, is significantly less in lopped plants than in those where lopping was done after the budlings had attained a height of 3 in. The

ults are in accord with those of Naik [1939] rking in Madras.

Lopping at the time of budding should also be carded as it causes serious injury to the stock nts by interfering with photosynthetic acti- ies [Mendel, 1937]. Many of these plants velop symptoms of root-rot and wilting and may ultimately die. This is, however, different from the 'bud-wilt' reported by Halma [1941] as in his case only the budling shows wilting leaving the stock plant unaffected. The degree of tolerance to lopping seems to vary from variety to variety; rough lemons being particularly susceptible and the shaddocks being specially resistant.

TABLE XII

Extent of mortality caused by lopping at budding on rough lemon and shaddock rootstocks

Scion	Rootstock	Date of budding	Number of plants lopped at budding	Number of dying plants	Percentage of mortality	Remarks
asi orange						
C. chrysocarpa Lush.) ..	Rough lemon	10. 9.41	17	5	29·41	
—Do.—	Shaddock	21. 9.41	15	1	6·67	
—Do.—	Rough lemon	10.10.41	15	4	26·67	
—Do.—	—Do.—	15.10.41	14	9	64·29	Irrigated
—Do.—	—Do.—	24. 6.42	33	25	75·60	
lencia (*C. sinensis* Osbeck)	Do.—	26. 6.42	15	10	66·67	
asi orange ..	Shaddock	30. 6.42	20	2	10·00	

The data furnished above are not the outcome any planned experiment but these were collected m the general nursery where lopping at budding s practised with a view to inducing early bud- eak. It may be seen that mortality is more ring summer months than during autumn. t even during autumn mortality increases te considerably if the lopped plants are subjec- to irrigation. General experiences in the rsery tend to show that all *Citrus* root- cks exhibit this intolerance to lopping at lding though some stand it better than others. ce lopping at budding does not exercise any urable influence either on the percentage of l-take or on the extension growth of the budling, re seems to be no justification for adopting it a nursery practice simply because it happens induce an earlier bud-break. The best course adopt is to cut back the stock to the bud in a gressive manner allowing some leaves of the ck plant to carry on essential photosynthetic ivities till the budling develops enough leaves take up this essential physiological function lusively.

SUMMARY

. The extent of seeds producing more than seedling each in nine citrus varieties has been ermined. Such seeds usually produce two dlings each and sometimes more. Seeds of ddocks and citrons appear to be mono- bryonic.

. The experiments on the effect of the stage maturity of fruits of the Khasi orange (*C. ysocarpa* Lush.) on the germinating capacity of seeds show that seeds of mature fruits seem to give a better germination than those of immature ones. Overripening of fruits lowers the viability of seeds to a small extent and prolongs the period of germination quite considerably. Immaturity of seeds has probably a more detrimental effect on the gametic than on the nucellar embryos.

3. Fresh seeds of the Mandarin orange ensure the highest germination which progressively deteriorates with increased doses of sunning.

4. An observation carried out on the viability of seeds with three grades of seed sizes and stored in a desiccator for 2½ months shows that the bigger the size the longer is the period for which the seeds remain viable and that the viability of seeds progressively deteriorates with the lengthening of storage periods.

5. Investigations into the possibilities of raising plants of citrus from root cuttings planted in open beds show that only citrons and lemons may be propagated by this method with appreciable success. Shaddocks, Seville orange, Mandarin orange and *C. macroptera* fail to form shoots from planted root cuttings.

6. Treatment with 'Hortomone A' causes a higher percentage of survivals in stem cuttings of those citrus varieties which are ordinarily amenable to propagation from cuttings but it fails to induce rootings in a variety which does not usually root from cuttings. This chemical, however, seems to have some stimulating influence in accelerating both root and shoot formation.

7. All citrus varieties may be successfully propagated by 'gootee'. Citrons, lemons and

C. macroptera put out roots much more quickly than the tight-skinned and loose-skinned oranges, Seville oranges and grapefruits.

8. The best season for bark-grafting is during July and August, i.e. during rains but the success depends on the continuity of wet weather. The failure of this method during winter months is attributed to the absence of active growing conditions in the stock plants and to the attendent low humidity. Bark-grafting is particularly suitable in inducing an earlier feathering in grapefruit which when budded takes an unusually long period, 3-6 months for bud-break.

9. Of the different methods of shield-budding tested both inverted 'T' and normal 'T' with a minute piece of wood adhering to the bud-shield have been found to give a higher percentage of success than when bud-shields are used with the wood removed.

10. The optimum season for budding under conditions obtaining at Burnihat, Assam, is from November to January, i.e. during winter; September and February seem to be the next best.

11. The period of bud-break for the Khasi orange (*C. chrysocarpa* Lush.) varies from 49 to 62 days and does not seem to show any distinct seasonal influence.

12. The practice of lopping the stock plants at the time of budding induces an earlier bud-break but lowers the percentage of bud-take and retards the extension growth in comparison with lopping after the budlings have formed few well-developed leaves. The former method causes serious injury to the stock plants, many of which develop symptoms of root-rot and consequent wilting. The best course to adopt in a nursery is to cut back the stock plant to the bud in a progressive manner.

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PHOSPHATE STUDIES ON THE PUNJAB SOILS

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(With plate VI and three text-figures)

ia exports on an average about 100,000 tons ones every year, the province of the Punjab e contributing roughly 23,000 tons. On the s of 25 per cent P_2O_5 available in bones, the jab soils are deprived every year of about 0 tons of this important chemical, and thus export of bones means a loss of great potential lth to the Punjab agriculturist.

itrogen and other plant food-constituents are ed to the soil in a number of ways; recupera- of nitrogen may even be effected by natural cesses but there exists no such agency for rning phosphates to the soil. It is not prizing, therefore, that attempts should have n made from time to time to utilize bone ures, this being the only indigenous phosphatic nure of the province, for improving the phos- te status of the Punjab soils.

he Department of Agriculture, Punjab, has n carrying out trials with artificial fertilizers, in the majority of earlier experiments, phos- tes either alone or in conjunction with other ures did not improve the yield of the crops n extent which would justify the use of these ures on an economic basis. Later on, experi- ts were carried out with different grades of meal on wheat and cotton. It was observed the addition of bone meal either singly or in ination with other materials did not increase yield nor was there any residual effect on the eeding crops. As a result of these experiments vas concluded that Punjab soils were quite in phosphates, and they did not require any tment with phosphatic manures. The more nt work on the Departmental farms, however, cates that soils from the sub-montane tracts as Rawalpindi and Gurdaspur do show a onse to phosphatic manures. Therefore, an stigation was taken up to study the phosphate us of the soils of the Punjab, viz. their power phosphate fixation, movement of phosphate ugh calcareous soil, and the response of areous and sub-montane types of soil to phos- e fertilization at different depths. The lts of the investigation have been reported in paper.

Review of earlier work

cGeorge and Breazeale [1932] report that the ve soil phosphates in calcareous soils are of carbonato-apatite group [$3Ca_3(PO_4)_2\,CaCO_3$], e solubility is a function of hydrogen ion concentration, the least being at a *p*H of 8·0 to 8·5. Hibbard [1935] described a number of factors affecting the fixation of phosphate, and considers calcium carbonate as a powerful agent of fixation. Midgley [1931] has found that superphosphate applied to the surface soil moves very slowly with irrigation water. Hockensmith [1923] has found a great response to phosphate application at a depth which is favourable for the absorption of phosphates by roots.

Methods of analysis

Phosphorus. This was estimated in extracts of suitable concentration by the ceruleo-molybdate method of Denigé as modified by Truog and Meyer, using the photoelectric colorimeter for colour measurements.

Available phosphorus. This was determined in Way's 1 per cent citric acid and Truog's 0·002N H_2SO_4 extract (buffered with ammonium sulphate).

Plant analysis. This was carried out according to the *Methods of analysis of the Association of Official Agricultural Chemists.*

Phosphate status of Punjab soils

In view of the continued removal of phosphates by farm crops from the soils without any corresponding addition in the form of manures, it becomes a matter of great concern to know the comparative content of phosphates in the different types of soils of the province. Total phosphorus and some of the important pedological characters of six typical Punjab soils, representing different climatic groups is presented in Table I.

Table I

Analysis of some typical Punjab soils

Place	Soil type	Total phosphorus* (parts per million)	Available phosphorus† (parts per million)	$CaCO_3$ (percentage)	Clay (percentage)	*p*H‡
Palampur (Kangra)	Hill soil	340	25·6	*nil*	25·27	5·0
Rawalpindi	Sub-montane	549	32·8	*nil*	26·30	6·8
Lyallpur	Alluvial	1207	366	2·85	15·83	8·0
Dhundi	Calcareous	811	146	12·35	49·08	7·8
Montgomery	'Bari'	1434	329	4·40	21·70	9·66
Lyallpur	Saline	832	143	5·56	15·23	9·18

*Total phosphorus estimated by the acid hydrofluoric method

†Available phosphorus estimated by extraction with 1 per cent citric acid.

‡*p*H determined with Beckmann's Glass electrode *p*H-meter

It will be seen from the above data, that the quantity of total phosphorus varies within wide limits. The Palampur and Rawalpindi soils contain comparatively much less total and available phosphorus than others. This deficiency is also indicated by the results of field experiments conducted at Rawalpindi, where the application of superphosphate at the rate of 25 lb. P_2O_5 per acre gave an increase of 5 md. of wheat per acre. In order to find out whether other mountain and sub-montane soils are also deficient in available phosphorus, soil samples from the mountainous tracts were also analysed for their available phosphorus

The results of these analyses are presented in Table IIA and B.

TABLE II A

Available phosphorus content of some more Punjab soils

Group A : Mountain and sub-montane regions

Locality			
Palampur fruit garden	Palampur potato farm	Palampur potato farm	Gurdaspur
50*	87*	87*	64*

*Available phosphorus (parts per million)

TABLE II B

Available phosphorus content of some more Punjab soils

Group B : Central plains

Locality			
Sheikhupura	Lahore	Ferozepur	Hissar
236*	302*	216*	195*

*Available phosphorus (parts per million)

The above figures indicate that the soils o mountain and sub-montane groups are also highl deficient in available phosphorus. It may b noted that the phosphorus in the soil exists i different forms; in acid soils (pH 5·0-6·8) phosphoru exists in the form of $AlPO_4$ and $FePO_4$, while i the neutral and alkaline soils (pH 7·0-8·5) it i present in the form of calcium phosphate $Ca_3(PO_4)_2$ In the former types of soils not only is the tota phosphorus content less but the iron and aluminun phosphates being less soluble, the replenishmen of the phosphate in the soil solution is compara tively much less which leads to a great phosphoru deficiency. Shedd [1921] has given the limit (0·08 to 0·10 per cent total phosphorus) wher phosphate applications will be useful, and accord ing to him the soils of the mountain and sub montane tracts of the Punjab fall in the categor of deficient soils.

DISTRIBUTION OF PHOSPHORUS IN THE SOIL PROFILE

Dunnewald [1929] has shown that in cultivated soils the amount of available phosphorus is at its maximum in the surface layer and that this figure gradually decreases with increasing depth of the soil. It may be noted that his finding offers a striking contrast with the distribution o potassium in the soil profiles where no such variations are observed. In order to see how the phosphates are distributed in the cultivated soils of the Punjab, samples representing different depths of profiles were obtained from some typical soils and the amounts of total phosphorus were determined in each case. The results are shown in Table III, A and B.

TABLE III A

Hcl-soluble phosphate content of two profiles

Soil		Percentage in air dry soil						
		1st 6 in.	2nd 6 in.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.
Montgomery normal	P_2O_5	0·164	0·159	0·150	0·141	0·138	0·143	0·153
	K_2O	0·730	1·070	0·570	0·630	0·590	0·710	0·725
Montgomery 'bari'	P_2O_5	0·197	0·185	0·167	0·161	0·141	0·134	0·123
	K_2O	0·690	0·925	0·755	0·855	..	0·980	1·000

TABLE III B

Available phosphorus content of some profiles

	Phosphorus parts per million					
	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.
Cultivated						
Ferozepur	255	138	138	22	Trace	Trace
Gurdaspur	64	29	29	29	22	14
Montgomery	189	138	80	36	29	29
Uncultivated						
Ferozepur	60	60	30	25	15	Trace
Montgomery	110	108	95	82	30	18
Lyallpur	63	82	71	62	25	12

The results given in the above tables are in ll agreement with those reported by Dunnewald 929]. In the case of both the soil profiles, iz. normal and 'bari', the amount of total as ell as available phosphorus decreases with ıcreasing depth of soil, the change being more ronounced in respect of available phosphorus. he distribution of potash behaves in a different ıanner. It is not possible to offer any detailed ɔmments on the manner of distribution of these vo important elements of soil fertility but obvi-ısly the accumulation of a high percentage of hosphorus in the upper layer cannot be due to ı upward movement of phosphates along with ther water soluble salts but it may be ascribed ɔ the action of growing plants which collect the hosphates from the lower layers and, through ıe plant residues after decomposition, they are ft behind on the surface where they may remain ɔund up with the soil due to its fixing power. ı the case of potash salts, owing to leaching, the mounts present in the lower layer are more. ı order to throw further light on the above ssumption a number of samples of cultivated ıd uncultivated soils were obtained from different ɔcalities in the Punjab and the amount of available hosphorus determined in them. The results of ıese analyses are given in Table IV.

TABLE IV

ıailable phosphorus content of adjacent cultivated and uncultivated (barren) soils

Soils	Phosphorus (parts per million)				
	Sheikhupura	Lahore	Ferozepur	Ferozepur	Hissar
ıltivated	236	302	106	221	195
ıcultivated	101	146	53	36	123

In all cases the available phosphorus is higher the cultivated area, inspite of the large amounts moved by the crops each year. This must be ıe partly to the above mentioned action of the ltivated plant, and partly due to other factors ch as manuring and cultivation.

FIXATION CAPACITY OF PUNJAB SOILS

Since fixation capacity of soil is an important ctor in the application of phosphatic fertilizers, was deemed necessary to have some idea of the ttent and nature of this factor in the case of the ınjab soils, since the ultimate use of these ferti-ers must depend on their availability after ing added to the soil, and the extent to which ey are in a position to move with the soil lution.

Fixation capacity of some of the typical soils were measured by the method of Heck [1934], and are reported in Table V.

TABLE V

Fixation capacity of some Punjab soils

Place	Phosphorus added (parts per million)	Phosphorus in filtrate (parts per million)	Percentag fixed
Palampur	400	146	63·5
Rawalpindi	400	320	20·0
Lyallpur	400	348	13·0
Dhundi	400	278	30·5
Bari	400	362	9·5
Saline	400	312	22·0
Sargodha	400	309	22·7
Sheikhupura	400	336	16·0
Lahore	400	371	7·2
Lahore	400	353	11·7

Majority of the soils allowed 309 to 371 parts of phosphorus out of 400 parts per million to pass into the filtrate, only Palampur and Dhundi Estate soils allowed 146 and 278 parts respectively. Palampur soil has developed under humid climate (rainfall about 90 in.) with excessive leaching. It contains large amounts of free aluminum and ferric oxide which are very reactive in fixing phosphates from solution. Dhundi soil, on the other hand, is highly calcareous, and possesses a high fixing capacity due to the presence of large amounts of calcium carbonate.

The method of measuring fixation is an arbitrary one, as the amount of phosphate fixed depends on a number of factors. The effect of two important factors namely the concentration of PO_4 in the solution, and the presence of $CaCO_3$ in the soil were further investigated. For this study 7·5 gm. of each of the three soils (Palampur, Rawalpindi and Lyallpur) were taken and increasing quantities of phosphorus were added in the form of H_3PO_4 to each, keeping the volume the same in all cases (50 c.c.) The suspensions were shaken occasionally for 24 hours, after which they were filtered and phosphorus determined in the filtrate. The amounts of phosphorus fixed for each concentration are graphically represented in the Fig. 1.

The actual amount fixed as also the percentage of the total added are shown in Table VI.

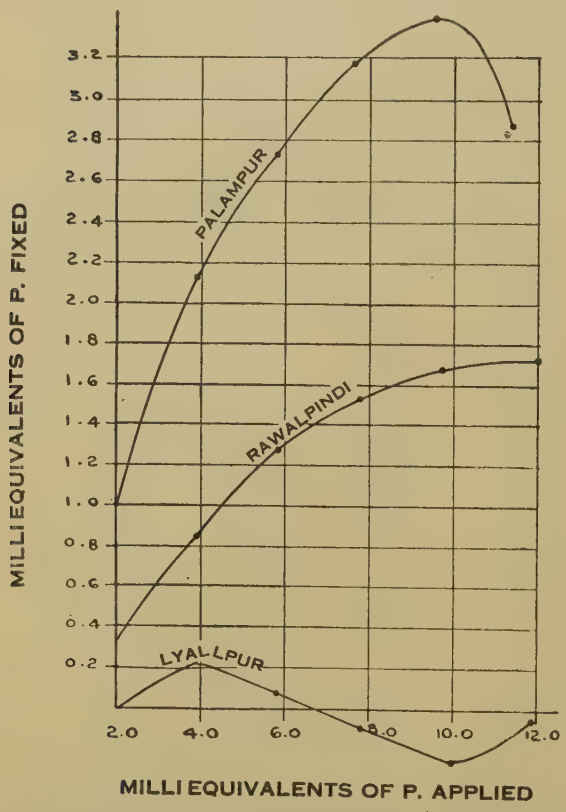

FIG. 1. Phosphorus fixation in different Punjab soils

TABLE VI

Percentage fixation of phosphorus with increasing concentration of phosphate solution

Phosphorus added (milliequivalents)	Phosphorus fixed					
	Palampur		Rawalpindi		Lyallpur	
	Milli-equivalents	Percentage	Milli-equivalents	Percentage	Milli-equivalents	Percentage
1·946	1·153	59·3	0·334	17·1	0·012	6·20
3·892	2·092	53·7	0·843	21·7	0·246	6·32
5·838	2·687	46·6	1·272	21·8	0·066	1·13
7·784	3·104	39·9	1·492	19·2	–0·057	–0·73
9·730	3·360	38·5	1·644	16·8	–0·202	–2·08
11·676	2·885	24·6	1·653	14·2	0·024	0·21

These figures also show that Palampur soil possesses the highest phosphorus fixation capacity, and the amount of phosphorus actually fixed in these cases goes on increasing up to a certain limit beyond which it begins to fall. In the case of Lyallpur soil when the amount of phosphorus added is more the fixation becomes even negative. It may be remarked that these results agree with those obtained by Ravikovitsch [1934]. The percentage of phosphorus fixed however varies indirectly, i.e. with increasing concentrations, the percentage of phosphorus fixed goes on decreasing.

Since most of the arid and semi-arid soils in the Punjab contain varying amounts of $CaCO_3$, the effect of this substance on their fixation power was also studied. A series of soils containing varying amounts of $CaCO_3$ was prepared by mixing requisite quantities of calcium carbonate. The soils were then wetted to optimum moisture content and left for 48 hours. They were then dried, pulverized and used for the estimation of the fixation power as before, adding increasing quantities of phosphorus in the form of a standard solution of H_3PO_4. The data are graphically presented in Fig. 2. It shows that the fixation power of the soil is largely affected by calcium carbonate and bears relationship with the amount of phosphorus added, it being less at lower concentrations but pronounced when higher concentrations are involved.

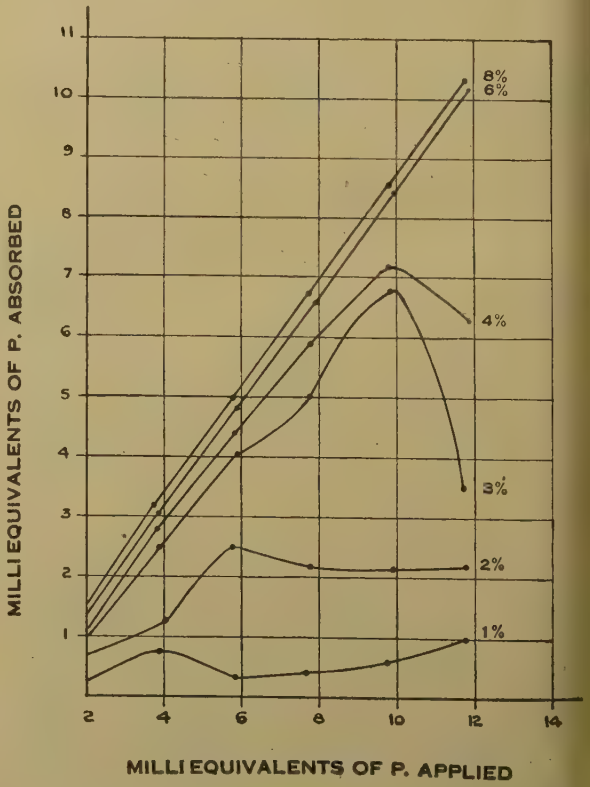

FIG. 2. Effect of calcium carbonate on phosphorus fixation

Phosphate penetration

Since soil acts as a powerful adsorbing agent for PO_4 ions, and further under field conditions the use of phosphatic fertilizers is comparatively very as compared with that used in the experiment described above, it would be expected that large proportion of the added phosphate would be adsorbed, and made immobile. Under these circumstances movement of phosphate would be restricted. In order to study the penetration of phosphate when applied as a top dressing, the following experiment was arranged.

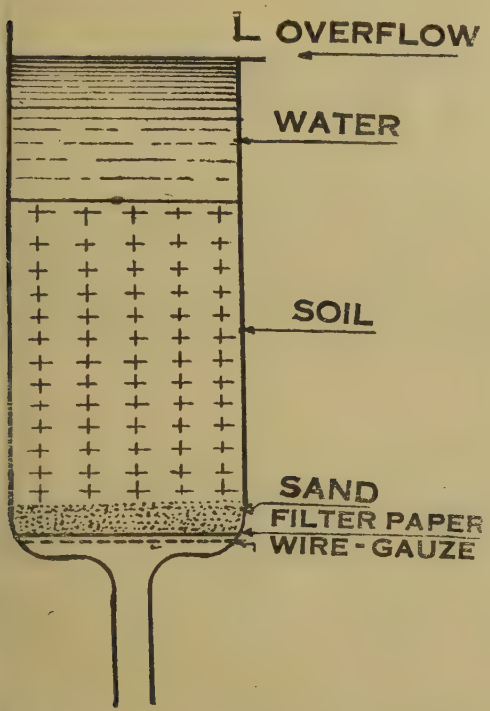

Fig. 3. Diagram of percolation tube

A series of brass percolation tubes was fitted with wire gauze, filter paper and a layer of sand at the bottom, as shown in Fig. 3. Into these tubes, soil in varying amounts was uniformly packed in order to give columns of different heights. Superphosphate, 0·02 gm., was sprinkled on the surface as top dressing. Distilled water corresponding to 3 in. irrigation was added on the top and allowed to percolate, the water filtering through was collected in various fractions and P_2O_5 content estimated by the colorimetric method. The results are shown in Table VII.

Table VII

Penetration of superphosphate through Lyallpur soil

Weight of soil used (Approximate height of column)	100 gm. 3 in.	200 gm. 6 in.	300 gm. 9 in.	100 gm. sand 3 in.
Fractions				
1st 100 cc.	14*	5*	3*	60*
2nd 100 cc.	3·5*	3*	3*	60*
3rd 100 cc.	3·0*	3*	3*	60*
Calculated percentage of total superphosphate moved with 6 in. irrigation	3·75	0·75	0·22	28·0

*Concentrations of phosphorus in leachings (colorimetric readings)

From the above data it appears that the percentage of super phosphate moving through different layers of soil with a 6 in. irrigation is very small, decreasing considerably as the column of soil increases in thickness. The first 100 c.c. fraction in the case of 3 in. layer had a much higher concentration than others, but in later fractions the concentration was the same in all cases thus indicating that the higher concentration in the first fraction of the 3 in. layer is mainly due to initial infiltration of fertilizer particles which ceases afterwards. That this resistance to penetration through soil is due to the colloidal nature is proved by comparing the above results with those obtained in the case of sand. These data lead to the obvious conclusion that since phosphatic manures do not move much with irrigation water, they should best be applied at a depth most suited for absorption by the roots.

Pot experiments

Depth of application and crop response

Phosphatic fertilizers are known to influence plants in the better development of the root system, better grain formation, earlier maturity resulting in increased yields. The effects produced are, however, proportionate to the phosphate deficiency in the soil. Field experiment with the application of phosphatic manures to the Punjab soils have however shown that generally speaking the soils of the Punjab plains do not respond to an application of phosphatic manures. The only cases in which certain response was observed, related to soils of the sub-montane tracts of Rawalpindi and Gurdaspur. As already mentioned, this latter group of soils also appears to be deficient according to the laboratory tests; the former group however does not fall into this category. It may be pointed out that in the field experiments

fertilizer was used as a top dressing in small doses. Kellog [1931] also states that calcareous soils such as are found in arid and semi-arid regions, and apparently possess a high content of phosphorus do not respond to low doses. Norris [1922], working on Madras soils also observed that increased yields were obtained only after continuous manuring with phosphates. These findings point to the necessity of supplying higher doses of phosphates to the Punjab soils. Besides, it has already been remarked that phosphates applied to the soil as top dressing do not penetrate into the subsoil to any appreciable extent. Therefore, a series of pot experiments on two types of soil using two different crops, was designed to test the availability of phosphates when applied in high doses, and to find out the most suitable depths at which these manures would be most effective.

Scheme of pot experiments

In the following series of experiments a uniform procedure was followed. 3,000 gm. of air dried, and sieved soil was packed in cylindrical glass pots 13 in. high and provided with a tubular at the base for aeration. The fertilizer was applied to these pots at varying depths in known quantities. Throughout the experiment the moisture percentage in each pot was maintained at a uniform level, the initial watering being done on the basis of the moisture equivalent of the soil. Tomato or wheat seedlings were transplanted into these pots. A record of growth measurements such as height, number of tillers, date of fruiting, etc. was kept for each pot. At the stage of maturity the plants were removed from the base, their green weights and oven dry weights being recorded.

Rawalpindi soil. The experiment was started on 21-10-43, using tomato as a test crop which according to Fisher [1935] is very sensitive to phosphatic manures. Single superphosphate at the rate of 400 lb. per acre, was applied and the following treatments were included, each being in three replicates :

(1) Control
(2) Application at the surface
(3) Application at 3 in. depth
(4) Application at 5 in. depth
(5) Application at 7 in. depth

Only two plants were allowed to grow in each pot, and on the ripening of the fruits they were harvested on 27-1-44. A photograph was also taken depicting their comparative growth at maturity (Plate VI, fig. 1). The green weight of each plant was determined, the weight of the fruit was also ascertained separately. The summary of the data is presented in Table VIII.

TABLE VIII

Growth, yield and analysis of tomato crop from pot experiments with Rawalpindi soil

Treatments	Height of plants in cm.		Green wt. of plants in gm.	Total wt. of treated plants in gm.	Wt. of fruit in gm.	Oven-dry wt. of treated plants in gm.	Percentage of P_2O_5 in oven-dry material	Total P_2O_5 removed in mg.
	Plant No. 1	Plant No. 2						
	23·0	16·5	8·0					
Control	24·0	18·5	10·8	39·0	*nil*	4·963	0·554	27·5
	16·0	30·5	20·2					
	41·5	40·5	29·1					
Surface application	28·0	41·5	29·4	84·2	6·2	11·995	0·490	58·8
	32·0	33·5	25·7					
	30·5	36·0	50·2					
3-in. depth	32·0	42·0	24·0	116·2	19·7	17·991	0·543	97·6
	36·5	41·0	42·0					
	47·0	45·0	50·0					
5-in. depth	41·0	39·0	37·0	150·0	5·0	19·812	0·458	90·7
	38·0	43·0	43·0					
	30·0	33·0	29·8					
7-in. depth	21·0	29·0	33·0	94·2	*nil*	12·753	0·464	59·2
	24·0	31·0	31·4					

It was observed that in the case of control pots, the tomato plants almost invariably showed a peculiar purple coloration on the lower side of the leaves. Cunningham [1922] made a similar observation that phosphate-starved barley plants grown in water cultures develop a reddish colour on the stems and a sickly purple in the leaves.

The yield data shows that though surface plication gives an increase in the yield of dry tter over the control, yet this increase is much s than the increase obtained with applications 3 in. and 5 in. depths. Besides, the fruit forma- n is also the best in the case of application at n. depth. The figures show that the unmanured nts contain the highest percentage of P_2O_5, the total quantity of P_2O_5 removed by the nts was higher in the case of 3 in. and 5 in. ths.

Lyallpur soil. The experiment was conducted the same lines as that with the Rawalpindi soil. The application of manures was made at the surface, at 2½ in., 4½ in. and 6½ in. depths. Instead of tomato the experiments were conducted with wheat. The method followed was the same as in the previous experiment. Two plants were kept as in the previous experiment. Seedlings were planted on 23-12-43, and the mature crop was harvested on 24-4-44. After the fresh and oven dry weights of the plant material had been recorded, the plant material was ashed and analysed for insoluble residue, calcium and phosphorus. The growth data and the results of analysis are given in Tables IX and X.

TABLE IX

Growth and yield of wheat crop from pot experiments with Lyallpur soil

Treatment	Average height per tiller in cm.	No. of tillers	Green wt. per treatment in gm.	Dry wt. per treatment		Grain/straw ratio
				Grain	Straw	
trol	56·5	16	39·5	12·85	15·70	0·819
face	61·5	16	41·1	13·37	16·40	0·815
n. depth	61·9	18	46·8	16·60	17·25	0·962
n. depth	60·5	17	43·2	14·77	16·60	0·890
n. depth	58·5	16	41·5	14·30	16·40	0·872

TABLE X

Proximate analysis of grain and straw of wheat from the pot experiments with Lyallpur soil

Treatment		Percentage on oven-dry material				Comparative yields	
		Ash	Insoluble residue	P_2O_5	CaO	Grain	Straw
ntrol	Grain	1·64	0·30	0·654	0·113	100	100
	Straw	9·06	4·68	0·047	0·489		
rface	Grain	1·73	0·15	0·800	0·084	104	104
	Straw	8·65	4·55	0·062	0·492		
½ in. depth	Grain	1·78	0·18	0·944	0·115	129	110
	Straw	9·37	4·92	0·081	0·688		
½ in. depth	Grain	1·71	0·16	0·924	0·121	115	106
	Straw	8·35	4·24	0·078	0·516		
½ in. depth	Grain	1·82	0·17	0·858	0·110	111	105
	Straw	8·44	4·62	0·066	0·492		

t is clear from the data that application of erphosphate has produced an increase of yield all cases, and has also increased the phosphate tent of the plants. As already observed the face application has also responded, but the ponse is much less than that obtained with per applications. The main points are mmarized below :

. Average height of tillers has been increased r controls in all cases of phosphate application, n. depth producing the highest tillers. In other cases the height of tillers decreased with the increasing depth of application. This can be judged from the photograph of the pots (Plate VI, fig. 2).

2. Application at a depth of 2½ in. gave a 29 per cent increase of grain over the control, but only a ten per cent increase in the case of straw. Grain to straw ratio becomes much higher in the case of 2½ in. depth than in other cases.

3. Application of superphosphate has greatly increased the percentage of P_2O_5 in the grain,

although there is not much difference in the percentage of CaO.

Discussion of results

Both the experiments have revealed the fact that great increase in yields can be obtained by applying phosphate at a suitable depth instead of applying it as a top-dressing, a practice usually in vogue. These studies have also shown that phosphate applied at the surface is fixed up in the soil and is unable to move into deeper layers with irrigation water. The effective root zone of the majority of field crops lies between 3 in. to 12 in. layer, and it is most essential that the manure applied should be available in the root zone. The most convenient depth which has given the best results under the conditions of the experiment is 3 in. to 5 in. This experiment is being extended in field conditions, in which case the manure is being applied at various depths by dropping it in the furrow.

Summary

1. According to the existing methods of estimating available phosphorus, the Punjab soils may be classified into two main-groups, (a) the mountain and the sub-montane soils which are deficient in available phosphorus, and (b) the arid and semi-arid plains which appear to be fairly well supplied with phosphorus.

2. The distribution of total and available phosphorus shows that the surface layer contains the maximum amount of phosphorus, both total and available, and that these amounts decrease with increasing depths.

3. The fixation capacity of different soils varies with the nature of soil and the amount of $CaCO_3$ present.

4. Pot experiments both with calcareous and non-calcareous soils have shown that application of phosphate at a depth of $2\frac{1}{2}$ in. to $4\frac{1}{2}$ in. gives a better response than the surface application.

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FIG. 1. Effect of phosphate placement in Rawalpindi soil. Crop : Tomato.
1. Control ; 2. Surface application ; 3. Application at 3 in. ; 4. Application at 5 in. ;
5. Application at 7 in.

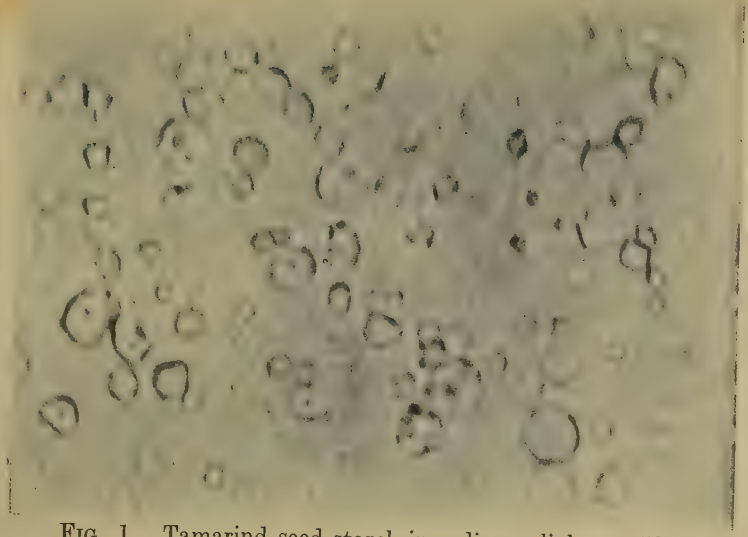

FIG. 1. Tamarind seed starch in ordinary light ×350

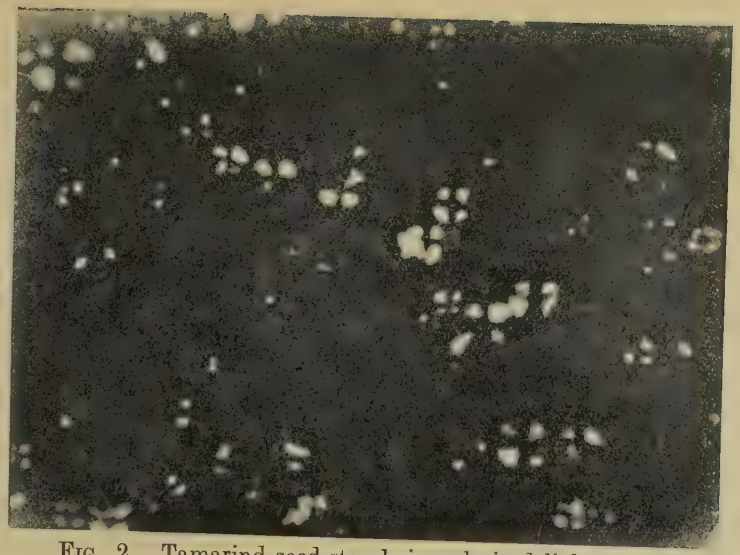

FIG. 2. Tamarind seed starch in polarized light ×350

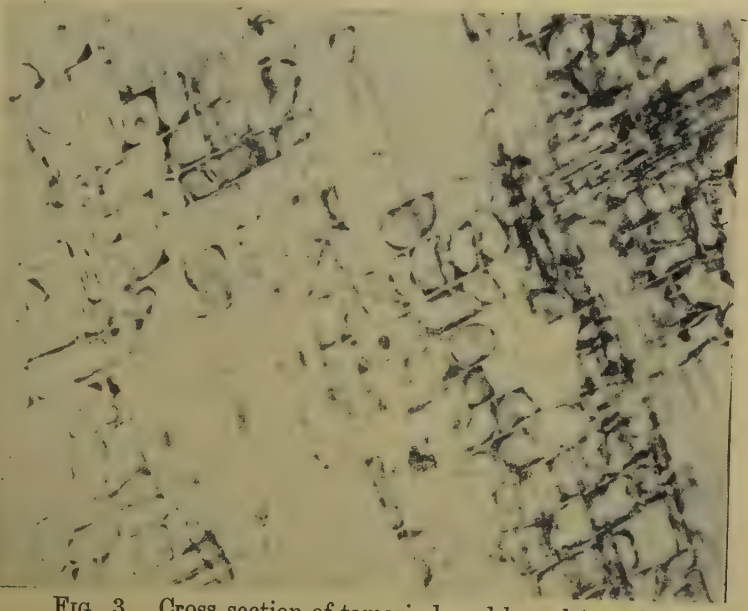

FIG. 3. Cross section of tamarind seed kernel (starch granules embedded in cells) ×350

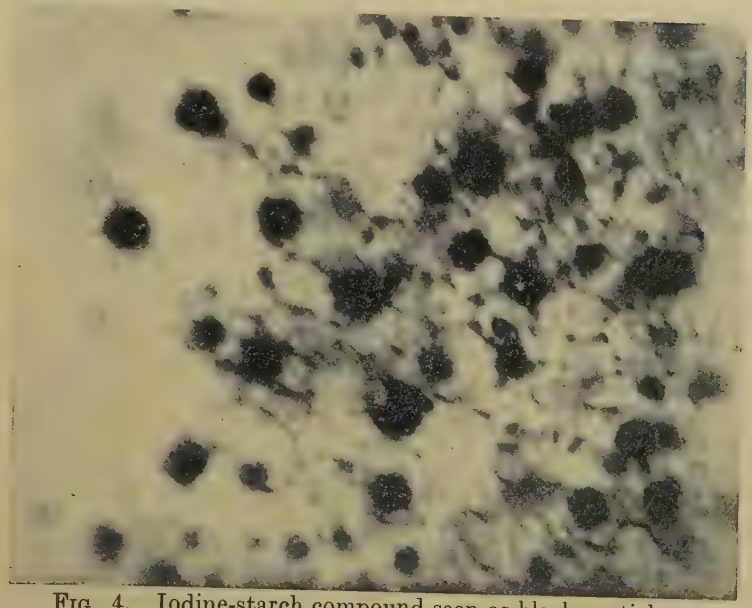

FIG. 4. Iodine-starch compound seen as black particles in the cells ×350

HEMICAL EXAMINATION OF THE SEEDS OF *TAMARINDUS INDICA*

NO PECTIN IN TAMARIND SEEDS

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(Received for publication on 28 March 1945)

(With Plate VII)

MARINDUS indica or the Tamarind tree is a ge deciduous tree that is found throughout India th in the wild and the cultivated state. It is handsome ever-green tree with large spreading anches and slender leaves, often growing to a ight of 70 to 80 ft. It is often cultivated as a ad side tree for its cool shade, but the well own fruit pods of the plant, with their delicate d flavour, are its most commercially valuable oducts.

According to Dymock [1893], the fruit is an oblong linear oblong, slightly compressed, curved or arly straight pendulous legume, of the thickness the finger, 3 to 6 in. in length, supported by a ody stock. It has a thin but hard and brittle ter shell or epicarp which does not split into lves or exhibit any evident sutures. Within e epicarp is a firm, acid juicy pulp, on the rface of which, and starting from the stalk, are nifying nerves; one of these extends along the rsel or concave edge, two others on either le of the ventral or convex edge, while between ese two there are usually 2 to 3 or 4 less regular d more slender nerves all running towards the ex and throwing out branching filaments. The ds are 4 to 12 in number and are enclosed in tough membraneous covering, surrounded by pulp.

The Indian commercial article forms a firm black ky mass. With the pulp are mixed the seeds, es and a small fragment of the shell. It is ually salted but for pharmaceutical purposes should be free from salt.

The preserved pulp of the tamarind fruit is cinal in the British Pharmacopoea. It consists a reddish brown sugary mass enclosing the stringy es founded within the pulp and the seeds en- sed in a tough membraneous coat. A corres- ding product often occurs in India as a black d mass of the pulp, more or less free from the es and husk, pressed into round cakes and served with salt.

Tamarind pulp contains large quantity of sugar l organic acids like acetic, citric and praticularly taric acid which latter it contains often to the ent of 6 to 8 per cent. The tartaric acid sent is partly free and partly in combination h potassium in the form of potassium hydrogen tarate or cream of tartar. No particular nciple to which the laxative action of tamarind ue is known.

The seeds of the tamarind fruit are small dark brown glossy nuts often rectangular in shape but rarely oval or round. They are about 12-15 mm. in length, 8-12 mm. wide and 3-5 mm. in thickness. The outer facets are slightly convex. The pericarp consists of a hard shell or covering enclosing a hard white kernel. The seeds are said to have good astringent properties. They are applied as poultice to boils after being boiled. The seeds are also crushed and pounded with water and applied to the crown of the head in cough and relaxation of the uvula.

The seeds, boiled or fried after removal of the outer skin, are also eaten by poor people in Malabar, Madras, Andhra, Bengal and Central Provinces particularly in times of a scarcity. Cameron [1894] mentions a cement or paste as made from the seeds which is used in dressing country-made blankets. In Central Provinces and Madras the seeds after frying and removal of the outer husk are ground to a flour in hand driven stone mills, and the products used in the same way as flour or *ata* from wheat or maize. It is stated that a number of sweetmeats are also made out of the preparation. According to *Yunani* medicine, the seeds are astringent, aphrodisiac, useful in giddiness and vertigo and applied externally in liver complaints and inflammation. They are also used in diarrhoea.

In view of the medicinal importance of the seeds it is very desirable that their chemical composition should be known with certainty. The first chemical examination of the seeds was done by Ghosh and Krishna [1942], who found that tamarind seeds consists of 55 per cent of kernels and 45 per cent of testa. The kernels on being analysed were found to contain:

Moisture	..	10·20 gm. per cent
Albuminoids	..	15·40 ,,
Oil	..	6·4 ,,
Crude fibre	..	5·0 ,,
Sugars	..	2·9 ,,
Tannins	..	1·6 ,,
Pectins	..	58·5 ,,
Ash	..	2·5 ,,
Total	..	102·5

In the same paper, Ghosh and Krishna made the most sensational announcement that the tamarind seed is a very rich source of commercial pectin, containing as it does nearly 64 per cent of this material in the dry weight of the kernel which can be easily extracted on a commercial

scale by following simple methods. They also showed that the pectin isolated in this way was quite pure, as it formed a stiff jelly when 1·5 gm. of the material was boiled with 65 gm. of sugar and 1 gm. of citric acid in 100 c.c. of water. The jelly did not break or run even when kept standing for over a month under proper sterile conditions.

In reviewing the work of the above authors, regarding the percentage of pectin in tamarind seed the present authors were surprized to note that whereas according to the analysis of Ghosh and Krishna, the percentage of pectin in the seeds was as high as 58·5, that of moisture was only 10·2. This is most extraordinary and yet unknown in the vegetable kingdom. For pectin is a substance like gelatin or agar-agar which is capable of retaining a large amount of moisture, and in nature pectin is always associated in fruits and vegetables with a large amount of moisture which is generally never less than 70 per cent of the total weight of the fruit or vegetable as shown in Table I.

TABLE I

Water and pectin contents of fruits or vegetables

Fruit or vegetable	Percentage of moisture (gm.)	Percentage of pectin as calcium pectate (gm.)
Apple (*Pyrus malus*)	87	1·5–2·5
Lemon pulp (*Citrus medica*)	85	2·5–4·0
Lemon peel „ „	77	3·6–3·8
Orange pulp (*Citrus aurantia*)	85	3·5–5·5
Orange peel „ „	76	3·5–4·2
Beet-root (*Beta vulgaris*)	92	1·0
Carrot (*Daucus carota*)	93	0·62
Onion (*Allium cepa*)	92	1·1–2·2
Leaves (various kinds)	70–87	0·6–1·2

Singh and Dutt [1941] working on the formation of jellies from Indian fruits have also shown that pectin yielding Indian fruits also contain a large amount of moisture as shown in Table II.

TABLE II

Moisture and pectin contents of some Indian fruits

Fruit	Percentage of Moisture (gm.)	Percentage of pectin as calcium pectate (gm.)
Wood apple (*Fronia elephantum*)	71·8	3·95
Guava (*Psidium guava*)	78·8	1·44
Karaunda (*Carissa carandas*)	89·0	1·23
Roselle— (*Hibiscus Sabdariffa*)		
Calyx	88·2	3·19
Entire fruit	82·66	2·48
Fruit only	76·4	1·02
Orange (*Citrus nobilis*)	88·6	1·2
Lemon (*Citrus limonum*)	85·08	2·76
Jujube (*ber*) (*Zizyphus jujuba*)	80·01	1·45
Banana (*Musa paradisca*)	73·6	1·19
Bel .. (*Aegle marmelos*)	68·8	2·03
Cape gooseberry (*Physalis peruviana*)	83·8	0·75

Further survey of the pectin yielding material from the vegetable kingdom indicated that pectin are always found in soft tissues of the plant like fruits and stems and pulpy roots and tubers and has never been known to occur in hard tissues like wood or seeds. This is nothing to be wondered at in view of the great water retaining capacity of vegetable pectins and their essentially slimy or 'pectinous' nature. Hence Ghosh and Krishna's discovery of 58·8 per cent of pectin in the fresh seeds of tamarind must come as a surprize to people acquainted with the occurrence and nature of pectins and pectic substances in general. In fact the discovery was so revolutionary in character and scope, that the present authors were prompted to re-examine the problem and subject the work of Ghosh and Krishna to very careful scrutiny.

On going through the analytical figures of Ghosh and Krishna regarding the fresh seed of tamarind, the present authors were surprized to find that the figures which carry the constituents up to 102·5 per cent, did not have any reference to starch at all in the material. A seed without starch is like an animal without protein, definitely unthinkable. Starch is absolutely essential for the growth of the germ cell and the young plant in the initial stages of its life and there is no seed known which is free from starch. Hence Ghosh and Krishna's analysis of tamarind seed as containing no starch must be regarded as positively erroneous. Even qualitative examination of the tamarind seeds, as we have found by actual experiment by extracting the powdered seeds with hot water and adding iodine solution to the cooled extract, gives a copious indication of the presence of starch by the intense blue colour that is produced. The intensity of the blue colouration that is thus produced with iodine is so great that it is quite reasonable to assume the presence of large quantities of starch in tamarind seeds, and this is not inconsistent with the agelong custom that has been prevailing in various parts of India of using these seeds as food materials. In fact from reports that the present authors have been able to get regarding the value of the seeds as food material, it seems quite apparent that they are used in the same way as starchy cereals like rice, wheat or maize, i.e. staple foods with similar nourishing qualities.

From what has been stated above it seems quite clear that tamarind seeds must contain large quantities of starch which Ghosh and Krishna have entirely missed in their analysis, and that it is quite unlikely that they should contain such a high percentage of pectin as 58·5. Besides the method of estimation of pectin as adopted by Ghosh and Krishna, namely alcohol precipitation method, has been shown to be definitely erroneous by a number of authors like Hinton

40], Allen [1937] and others who have pointed that alcohol precipitates not only pectins but ny other substances like albuminoids, starches, anic acids, gums and mucilages, thus making s process of extraction entirely worthless, rticularly where pectins are associated with h materials.* According to most well known thors the quantitative estimation of pectin can best carried on by the method of Emmett and re [1926] as modified by Nanji and Norman 28] in which the pectic substances present in y plant material are converted into calcium tate and estimated as such. By following this thod the present authors tried to estimate the ount of pectin present in tamarind seeds, but to ir great surprize they found that they contained pectin at all, as no precipitate of calcium pectate ld be obtained under any circumstances.

According to Meyers and Baker [1934] pectin the unhydrolysed condition is mono-arabino-no-galacto-diacetylhepta-methoxyl-octagalactu-ic acid. The nucleous of the pectin molecule octa-galacturonic acid most likely formed by union of two molecules of tetra-galacturonic d with the elimination of one molecule of water. e tetra acid is most likely formed into a ring npound by the combination of four molecules galacturonic acid with the elimination of four lecules of water. Seven of the eight carboxyl ups of the octa-galacturonic acid are methylated, the other one is free. On this basis, the pirical formula for pectin would be C_{70} H_{98} O_{58} h a molecular weight of 1,866,784.

Further, Baker and Goodwin [1939] while iewing the work of various authors have stated ' Present opinion definitely favours the umption that pectin is a chain compound nposed of galacturonic acid groups. In this ain compound the carboxyl groups are 75 per t methylated (11·92 per cent CH_3O) and the sition of the free carboxyl is arbitrary '. The nstitution of pectins has been fully dealt with Hinton [1940]. All these show that pectin uld contain methoxy groups which can be ily estimated by Zeissel's method. A determina-n of methoxy groups by the Zeissel's method o gave negative results, showing the complete absence of pectin in tamarind seeds. It seems therefore quite apparent that Ghosh and Krishna must have mistaken the larger amount of starch present in tamarind seeds to be pectin. It is a pity that they hastily announced their erroneous discovery to the public without taking trouble to make sure of their grounds by accurate experimentation.

The jellies which Ghosh and Krishna obtained with tamarind seed are undoubtedly starch jels. It is a well known fact that many varieties of starch have extraordinary power of jellification, specially in presence of sugars and several varieties of sweetmeats are commonly prepared in this way by *halwaies* all over the country. Properly made jellies prepared from pectin are very durable and remain firm for years under ordinary conditions of storage whereas starch jellies last only for a few days unless they are kept under aseptic conditions. It is significant that Ghosh and Krishna have mentioned that the jellies prepared by them from tamarind seeds remain firm for a month only under proper sterile conditions.

Still another error which Ghosh and Krishna apparently made was in the estimation of the proportion of testa and kernel in the seeds. They have given the figures of 45 per cent of testa and 55 per cent of kernel whereas we actually found that the proportions were 30 per cent and 70 per cent respectively.

Experimental

Tamarind seeds were collected from the local market and they were well washed, cleaned and dried in air. The testa and kernel in the seeds were estimated by the usual methods and were found to be 30·22 and 69·78 per cent respectively. The moisture in the kernel was estimated by heating a weighed amount of powdered kernel in an air oven at 40°C. for 2 hours and then at 80°C. for two hours and afterwards at 110°C. till a constant weight was obtained. The loss of weight represented moisture which was 10·2 per cent as an average of a few readings. For estimating pectin a number of experiments were carried out as stated above both for getting pectin as calcium pectate and methoxy group by Zeissel's method but there was no pectin.

Estimation of fixed oil

It was done by extracting the seed powder in a Soxhlet apparatus with petroleum ether (boiling 40°-60°C.). The fixed oil was found to be 6·8 per cent as an average of two estimations.

Estimation of albuminoids

They were determined by estimating the percentage of nitrogen by Kjeldahl's method in the

*According to Allen's *Commercial Analysis* and Hinton's *it Pectins*, the estimation of pectic substances as calcium tate, a method first introduced by Carre and Haynes 22] forms the only satisfactory process for the accurate ermination of these substances. Calcium pectate is oluble even in extreme dilution and is a substance of nite composition into which all pectins are readily con-ed. Its insolubility in dilute acetic acid allows the oval of the calcium salts of all organic acids commonly with in plant products except oxalic acid [Allen, 1937]. etailed method for estimating pectin as calcium pectate been mentioned by Hinton [1940].

seed powder and multiplying the figure with the factor 6·4. Our result is 20·12 per cent as an average of three estimations while it is 15·4 per cent in Ghosh and Krishna's paper.

Reducing sugars

Reducing sugars were estimated by extracting a weighed quantity of the powdered kernel with water and titrating with standard Fehling's solution. The result was 2·8 per cent estimated in terms of glucose as an average of two estimations.

Crude fibres

Fibre was estimated according to the method given by Allen [1937]. It was found to be 2·4 per cent.

Ash

Estimated by incinerating a weighed quantity of the powdered kernel in a silica crucible until a constant weight was obtained. It was found to be 2·45 per cent.

Tannin

As no tannin could be detected in the powdered kernel by qualitative examination the question of estimation did not arise.

Determination of starch

Starch was estimated both by hydrolytic and non-hydrolytic methods. Hydrolysis with enzymes could be done only with malt-diastase. As Taka diastase which can hydrolyse both α- and β-starches easily to maltose and dextrin was not available in the market, malt diastase had to be employed. Fresh samples of this diastase were prepared in the laboratory as mentioned by Onslow [1929] and they differed in their activity as time for complete hydrolysis was quite different in each of the samples. O'Sullivan's method [Allen 1937] for the estimation of starch was used for diastatic hydrolysis but generally hydrolysis was not complete as β-starch is hydrolysed by malt diastase only under optimum *p*H condition which could not be obtained in every case. In some cases the hydrolysis was very quick and with a very active sample of diastase the hydrolysis was complete in an incubator running at 38°C. within 24 hours. Normally diastase required about three days for changing the starch completely to reducing sugars. Maltose was estimated by Fehling's solution and dextrin calculated from the rotation of the solution in a polarimeter. Results obtained by this method gave starch up to 50 per cent. The result was less by 14-15 per cent malt as diastase is not the proper enyzyme like Taka diastase for completely hydrolysing starch. There is another objection to using enyzymes as they introduce simultaneously bacterial contaminations and the necessity for a secondary conversion of the residual dextrins, which require considerable time. Allen [1937] also mentions that the results obtained by Sullivan's methods are 12-13 per cent lower than the actual value. The high content of albuminoids present in the seed was mainly responsible for the difficulties encountered in the estimation of starch. Filtering difficulties could only be overcome by filtering through an acid-washed layer of sand. Till the time starch and albuminoids were present it was most difficult to filter through a filter paper.

Acid hydrolysis [Scott, 1939] gave the exact result. In this method a few gm. of the seed powder (80-100 mash sieve) were taken in a round bottomed flask, 200 ml. of water and 5 ml. of glacial acetic acid were added. The flask was connected to a reflux condenser and the contents boiled for 1½ hours. Afterwards 15 ml. of concentrated Hcl were added and the mixture boiled under reflux for a certain period. Starch was changed to reducing sugars. After neutralizing the acid with sodium carbonate the reducing sugars were estimated either by direct titration with standard Fehling's solution or indirectly by Bertrand's method wherein the equivalent starch was easy to calculate as one ml. of N/30 $KMnO_4$ is equivalent to 0·0011 gm. of starch. In cases where the amount of glucose or reducing sugar was obtained by direct titration, the glucose figure was multiplied with 0·93 for getting the equivalent amount of starch. About acid hydrolysis a very important fact is necessary to mention. When the mixture was refluxed with the acid for half an hour the percentage of starch obtained was near about 47 per cent. After two hours heating with acid the result was 53-55 per cent. A number of experiments had to be carried out to get the maximum value. After about 8 hours of heating 65 per cent of starch was obtained. In some experiments the solution was heated for a greater time uptil a maximum of about 15 hours but the result did not exceed more than 65 per cent in these cases. Acid hydrolysis needed sufficient time for complete hydrolysis but it seemed to be the most accurate method.

In non-hydrolytic methods starch is dissolved in a solvent and then recovered and weighed or precipitated from the solvent in the form of a derivative. Starch dissolves in aquous NaOH and then precipitated by alcohol as starch is insoluble in alcoholic NaOH. Baumert and Bode's modifications as mentioned by Allen [1937] was used for this purpose. Another method used by Rask [1927, 1928, 1930] in America was used for this purpose. It is a very rapid method for

imating starch in grains but it seems to fail those cases where albuminoids are more than 13 per cent due to the filtration difficulties. The nciple used is the same alcoholic precipitation t all the solutions of starch in concentrated acid ld not be filtered even under suction and for t purpose acid-washed sand had to be used. t as this did not give such a clear filtrate as that tained by suction, the results were not consistent. trate obtained either by suction or sand could t give a compact precipitate with alcohol. The cipitate was jelly like and could not be obtained a compact form by any way. With the filtrates tained by suction, results obtained were only to 40 per cent. Some more work is needed on sk's method for avoiding the various difficulties this particular grain.

Modification of Rask's method as used by rd and Kent-Jones [1934] as mentioned Radley [1943] was also used wherein a centri- ge was employed every time, but here again the cipitate was of a jelly form and as no compact ss could be obtained the results were not con- tent.

icroscopical examination

Fine powder (100 mash) of the seeds was amined under a microscope and the starch nules were clearly seen. Micro-photographs re taken both with ordinary and with larized light. (Plate VII, figs. 1 and 2) Starch nules are not only oval but of a few other pes as well. A cross section of the seed was n prepared for examination by following an borate procedure consisting of softening kernel, its dehydration and subsequent pregnation with wax according to well known thods used by botanists. This procedure was nd necessary as on account of the hardness of e kernel and its very brittle nature, a section hand microtome was not possible. Sections of out 5 μ thickness were obtained by a mechanical crotome and a micro-photograph (Plate VII, fig. 3) one such section is appended herewith which ows clearly the starch granules in cells. Another tion was stained very lightly with iodine and cro-photographed (Plate VII, fig. 4). The dark rticles, representing the starch granules on which line has acted forming the deep blue iodine- arch compound, are embedded in the cells. The agnification employed in all these cases was out 350 diameters.

Summary

Tamarind seeds have been chemically analysed and, contrary to Ghosh and Krishna's result, it has now been definitely ascertained that they do not contain any pectin at all. The 64·4 per cent of pectin found by Ghosh and Krishna is really starch which they have mistaken for pectin. The complete analysis of the kernel of dry tamarind seeds as determined by the present authors is given below :

Starch ..	65·20 gm.	per cent
Albuminoids ..	20·12 „	„ „
Oil	6·80 „	„ „
Reducing sugar ..	2·80 „	„ „
Crude fibre ..	2·43 „	„ „
Ash	2·45 „	„ „
Total ..	99·80	

From the above it is easily seen that tamarind seeds contain a large percentage of starch and albuminoids and as such would constitute, if properly processed and manufactured, a very important staple food comparing favourably in food value with wheat and maize.

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STUDIES ON COMPOST

INFLUENCE OF ADDITION OF SOIL ON CARBON AND NITROGEN ECONOMY DURING COMPOSTING*

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One of the special features of the Bangalore process of composting is the utilization of the agency of earth for preventing losses of nitrogen and obtaining increased yields of humified organic manure [Acharya, 1939, 1944]. The beneficial effect of an earth cover in the preparation of composts has been reported upon by Hutchinson [1916] and Ayyar [1928, 1933]; and earth, in the form of canal mud has been used for centuries by the Chinese in building up their composts [King, 1926]. But it must be admitted that the use of earth in the above cases appears to have been based mainly on empirical experience and observations on a field scale, rather than on any systematic experiments carried out to test the point under controlled laboratory conditions. Further, the influence of earth on carbon economy during composting does not appear to have received any attention so far.

It was therefore considered advisable to carry out comparative trials on a laboratory scale under controlled conditions so as to examine the influence of addition of earth on the composting process. The trials have now been repeated over three seasons and they have yielded similar results in all the three seasons. Typical results obtained in one batch of trials are reported in the present paper.

Experimental

The trials were carried out in shallow, wide, glazed jars arranged in three series: series A carrying mixed organic refuse only without the addition of earth, series B carrying 2000 gm. of garden soil only, without the addition of organic refuse and series C containing a mixture of the organic refuse with the soil. In series B and C, 2000 gm. of air-dry surface soil (red-loam) sieved through a 10 mesh sieve, were also added. In series C, the soil was uniformly mixed with the refuse, with the addition of the required quantity of water to keep the mass moist and in good tilth. Only water was added to series B.

The mixed refuse added to each jar in series A and C consisted of 150 gm. *ragi* (*Eleusine coracana*) straw, 50 gm. coarse grass, 40 gm. *hariali* (*Cynodon dactylon*) grass, 50 gm. mixed weeds, 70 gm. *hongay* (*Pongamia glabra*) leaves and 75 gm. cattle dung. All the materials except the dung were air-dried and enough of each material for 56 jars was first gathered, cut into bits and mixed well, before weighing out aliquots for the jars. The required quantity of cattle dung was separately weighed out (on a fresh weight basis) for each jar and was made into an emulsion with water and mixed uniformly with the whole material in each jar.

Each series consisted of 28 jars, four of which were removed, for purpose of analysis in quadruplicate, at the end of 1, 2, 4, 8, 12, 16 and 20 weeks of decomposition.

At the end of a definite period of aerobic fermentation four jars were taken out from each of series A, B and C; the contents were dried at 40°-50°C., then allowed to air-dry in the laboratory and weighed and powdered. The material from each jar was mixed well, spread on a sheet of paper and samples of about 20-50 gm., composed of small quantities taken from different portions of the mass, were taken in duplicate for analysis. Such samples were further pulverized and aliquots were taken for the determination of (a) moisture, (b) carbon, (c) total nitrogen, and (d) ash. Carbon was determined by the chromic oxidation method of Acharya [1936] and total nitrogen by the Gunning's modification of the Kjeldahl method [A.O.A.C., 1935].

The data obtained are presented in Tables I to V. Table I gives the analysis of the raw materials used for composting and Table II the total quantities of dry matter, carbon, nitrogen and ash taken initially in each of the series A, B and C. Tables III, IV and V give the total quantities of residual materials remaining in the jars after each interval of composting, their analyses and the total quantities of dry matter, carbon, nitrogen and ash recovered as well as the C/N ratio of the material at each stage.

*Work carried out under the Compost Scheme of the Imperial Council of Agricultural Research

TABLE I

Analysis of raw materials used

Materials	Moisture in gm. per cent	Analysis on dry basis in gm. per cent		
		Carbon	Nitrogen	Ash
gi straw	4·24	39·48	0·639	17·54
atcha grass	5·12	40·11	0·851	15·70
ariali grass	6·21	41·05	1·772	12·47
xed weeds	3·64	26·56	1·371	55·42
ngay leaves	5·96	41·07	2·117	12·66
ttle dung	80·6	6·52	0·307	32·99
il	2·1	0·712	0·0686	96·63

TABLE II

Quantities of constituents taken initially

Material	Quantity of fresh material in gm.	Quantities of constituents in gm.			
		Dry matter	Carbon	Nitrogen	Ash
gi straw	150·0	143·6	59·22	0·959	25·2
atcha grass	50·0	47·4	20·06	0·426	7·5

TABLE II.—*Contd.*

Material	Quantity of fresh material in gm.	Quantities of constituents in gm.			
		Dry matter	Carbon	Nitrogen	Ash
Hariali grass	40·0	37·5	16·42	0·709	4·7
Mixed weeds	50·0	48·2	13·28	0·686	26·7
Hongay leaves	70·0	65·8	28·75	1·482	8·3
Cattle dung	75·0	14·6	4·89	0·230	4·8
Total quantity in series A (compost without soil)	435·0	357·1	142·62	4·492	77·2
Total quantity in series B (soil only)	2000·0	1958·0	13·94	1·343	1892·0
Total quantity in series C (compost with soil)	2435·0	2315·1	156·56	5·835	1969·2

TABLE III

Decomposition of mixed refuse without the addition of soil

	Period of incubation	Air-dry weight in gm.	Total dry matter in gm.	Analysis on dry basis in gm. per cent			Total quantities recovered in gm.			C/N ratio
				Carbon	Nitrogen	Ash	Carbon	Nitrogen	Ash	
1	Initial	..	357·1	39·93	1·258	21·62	142·6	4·492	77·20	31·75
2	1 week	342	308·9	38·29	1·249	24·31	118·3	3·859	75·12	30·66
3	2 weeks	303	274·5	36·82	1·394	27·61	101·1	3·828	75·78	26·40
4	4 „	264	237·2	33·98	1·565	32·56	80·6	3·713	77·24	21·71
5	8 „	232	208·9	31·30	1·746	36·44	65·4	3·648	76·13	17·93
6	12 „	211	190·5	29·34	1·875	41·02	55·9	3·572	78·12	15·65
7	16 „	202	183·4	27·59	1·900	42·45	50·6	3·484	77·86	14·52
8	20 „	195	174·7	25·87	1·984	44·78	45·2	3·465	78·22	13·04

The figures given in Table III would show that hen mixed refuse is decomposed without the ddition of soil, there is considerable loss of trogen, amounting to nearly 23 per cent of the itial nitrogen content (Table VI). This loss in trogen is not revealed by the percentage analysis the residual material (Table III), since the trogen content of the residue shows a progressive crease with period of decomposition; when owever the nitrogen percentage is multiplied by e total dry matter present, the loss of nitrogen found to be of a high order. A perusal of the gures for total nitrogen present in the residue at fferent periods of decomposition (Table III) ould show that the loss occurs in two definite ages. Soon after the dung emulsion is added the refuse and active fermentation starts, i.e. the first week of decomposition there is rapid loss of nitrogen, which in the present case amounts to about 14 per cent of the initial nitrogen content (Table VI). This is followed by a second stage of slower but progressive loss of nitrogen accompanying the progressive decomposition of the manure. It must be remembered that the refuse has been decomposed in this experiment aerobically.

The changes in total carbon recovered in the residues at different periods of decomposition follow a course roughly similar to the changes in nitrogen; but on account of the greater rate at which carbon is lost as compared to nitrogen, there is a progressive narrowing of the C/N ratio of the residue from about 32 : 1 to about 13 : 1.

The addition of earth to decomposing refuse exerts a profound influence on the carbon and nitrogen economy of the system, as shown by the

data contained in Table V. In this case, there is no loss of nitrogen ; on the other hand, there is a slight but significant fixation of atmospheric nitrogen taking place, the quantity so fixed in 20 weeks amounting to about 2 to 2½ per cent of the initial nitrogen content of the system. Deducting from the values given in Table V the control values for carbon and nitrogen present in the soil only at the end of 20 weeks incubation (Table IV) it is found that 47·55 gm. of carbon and 4·352 gm. of nitrogen are recovered from the original refuse in presence of soil, as compared to 45·2 gm. of carbon and 3·465 gm. of nitrogen recovered from the same refuse when composted without the addition of soil. The difference is specially marked in the case of nitrogen, where the addition of soil has increased the recovery by nearly 25 per cent (Table VI).

The rate at which the C N ratio of the residue narrows (Tables III and V) is also greater in the refuse plus soil compost, indicating that humification proceeds more rapidly in presence of soil. Part of the narrower C/N ratios observed in the refuse plus soil composts, is no doubt attributable to the better conservation of nitrogen secured in the above composts.

TABLE IV

Changes in soil only

Serial No.	Period of incubation	Air-dry weight in gm.	Dry matter in gm.	Analysis on dry basis in gm. per cent		Total quantities recovered in gm. per cent	
				Carbon	Nitrogen	Carbon	Nitrogen
S1	Initial	2000	1958	0·712	0·0686	13·94	1·343
S2	1 week	2000	1956	0·726	0·0714	14·20	1·396
S3	2 weeks	2000	1956	0·764	0·0742	14·94	1·451
S4	4 „	2000	1954	0·771	0·0761	15·07	1·487
S5	8 „	1990	1942	0·744	0·0762	14·45	1·480
S6	12 „	1990	1942	0·723	0·0802	14·04	1·557
S7	16 „	1980	1934	0·706	0·0817	13·66	1·581
S8	20 „	1980	1934	0·685	0·0834	13·25	1·614

TABLE V

Decomposition of mixed refuse in presence of soil

Serial No.	Period of incubation	Air-dry weight in gm.	Total dry matter in gm.	Analysis on dry matter in gm. per cent			Total quantities recovered in gm. per cent			C/N ratio
				Carbon	Nitrogen	Ash	Carbon	Nitrogen	Ash	
CS1	Initial	2390	2315	6·766	0·2522	85·07	156·6	5·835	1969	26·83
CS2	1 week	2330	2265	6·012	0·2561	86·16	136·2	5·802	1952	23·47
CS3	2 weeks	2285	2225	5·365	0·2628	87·40	119·4	5·849	1945	20·41
CS4	4 „	2240	2184	4·765	0·2667	88·90	104·1	5·824	1942	17·87
CS5	8 „	2200	2149	4·211	0·2721	89·97	90·5	5·848	1933	15·47
CS6	12 „	2175	2122	3·639	0·2777	91·35	77·2	5·894	1938	13·10
CS7	16 „	2150	2098	3·160	0·2839	92·85	66·3	5·956	1948	11·14
CS8	20 „	2120	2071	2·936	0·2880	93·76	60·8	5·966	1942	10·20

TABLE VI

Percentage recoveries of carbon and nitrogen

Decomposition in weeks	Percentage recovery of carbon in gm.			Percentage recovery of nitrogen in gm.		
	Refuse only	Soil only	Soil+Refuse	Refuse only	Soil only	Refuse+Soil
1. Initial	100·00	100·0	100·00	100·00	100·0	100·00
2. 1 week	82·96	101·9	86·96	85·92	104·0	99·40
3. 2 weeks	70·89	107·2	76·25	85·23	108·0	100·2
4. 4 „	56·52	108·1	66·46	82·66	110·8	99·79
5. 8 „	45·86	103·6	57·79	81·23	110·3	100·2
6. 12 „	39·20	100·7	49·29	79·52	116·0	101·0
7. 16 „	35·49	97·97	42·34	77·57	117·7	102·1
8. 20 „	31·70	95·04	38·83	77·14	120·1	102·2

Discussion

The present experiment does not show in what rm the nitrogen is lost when mixed refuse is composed aerobically with the addition of dung nulsion. Experiments are under way to examine is question in detail, but presumably a good rtion of the loss occurs in the form of ammonia bsequent data unpublished).

Shrikhande [Eden, 1939] who followed the composition of *Gliricidia* and tea leaves under ntrolled conditions found that in the case of *iricidia*, (C : N ratio near 11 : 1) more than 50 r cent of the initial nitrogen was lost as mmonia. In the case of tea leaves, however, : N ratio near 17 : 1), the loss amounted to out 9 per cent only, and of this only 0·6 per nt was recovered in the form of ammonia. mewhat similar results were obtained by yaraman [1941] who followed the total losses of trogen, but did not measure the quantity of mmonia evolved (Table VII).

Table VII

itial C/N ratio and percentage of initial nitrogen lost

Material	Initial C/N ratio	Percentage of initial nitrogen lost
Dadap leaves	12·3	50·6
Tea	19·1	14·0
Grevillea	36·7	2·3 (gain)

A great deal of work has been done on the rate ammonification and nitrification of green anures [Waksman, 1938 ; Eden and Shrikhande, 39] and the data obtained show that, in general, ant materials of C/N ratio narrower than 20 : 1 f nitrogen content, say above 1·8 per cent on y matter) tend to liberate ammonia on decomsition, whereas materials of C/N ratio wider an 20 : 1 (possessing a nitrogen content of say, wer than 1·8 per cent on dry basis) do not liberate mmonia, but on the other hand suffer from trogen 'hunger', as shown by their ability to added soluble nitrogen in the insoluble organic rm [Hutchinson and Richards, 1921 ; Richards d Norman, 1931].

Applying the above criteria to the present periment it would appear as though mixed fuse having an initial C/N ratio of 31·75 : 1 able III) should on decomposition show a tenncy for fixation of additional nitrogen and rtainly for no appreciable loss of nitrogen. The tual loss observed, however, is considerable, mounting to over 20 per cent of the initial nitrogen ntained in the refuse.

The above loss is explainable on the basis that the limits of C/N ratios indicated by previous workers as controlling nitrogen losses, apply only to single plant materials of a uniform type, and not to mixtures of different plant materials. In the case of such mixed refuse, the over-all C/N ratio of the mixture may not possibly give any indication of the behaviour of the individual constituents. It is probable that microbial attack may start vigorously on such of the components of the mixture as possess narrow C/N ratios, while the more resistant components of wider C/N ratios may remain unattacked in the early stages. Thus, the ammonia that may be liberated in the earlier stages from the components of narrow C/N ratios may be lost in part before it is used up by the micro-organisms for the decomposition of the components of wider C/N ratios. In the present experiments, the over-all C/N ratio of the mixed refuse in series A is 31·75, but some of the constituents such as *hongay* leaves, mixed weeds and *hariali* grass possess narrow C/N ratios of 19·40, 19·37 and 23·16 respectively, while other components such as *ragi* (*Eleusine coracana*) straw and *katcha* grass possess wide C/N ratios of 61·79 and 47·13 respectively ; and the hypothesis set out above would satisfactorily explain why there is a loss of over 20 per cent of the nitrogen from the above mixture.

The beneficial effect of earth in preventing nitrogen losses could be attributed to the following factors :

(1) The presence of soil colloids, which might absorb and retain the ammonia evolved.

(2) The influence of the type of microbial population present in the soil, which might utilize and fix up the ammonia evolved more rapidly than the microbial population present in decomposing plant refuse. Some recent work of Mr Pillai in this laboratory (unpublished data) has shown the important role played by protozoa in the activated sludge process, in improving the nitrogen content of sludge by fixation from sewage. The protozoa not only control the rate of liberation of ammonia by bringing down bacterial numbers, but also serve to fix rapidly in their own bodies the ammonia that is evolved in the system. It is possible that a similar role may be played by protozoa present in the soil added to compost, thus serving to minimize the over-all losses of nitrogen considerably.

(3) A part of the nitrogen loss from the refuse, may be masked by a simultaneous fixation of atmospheric nitrogen effected by the micro-organisms present in the added soil. A reference to Tables IV and V would show that 2000 gm. of soil when incubated alone fixed 0·271 gm. of nitrogen from the air, but a mixture of the above quantity of soil with plant refuse fixed only 0·131

gm. of nitrogen. The difference might probably represent the amount of nitrogen lost from the organic refuse, since the nitrogen fixing power of soils has, in general, been found to be improved by the addition of refuse of comparatively wide C/N ratios.

In the absence of more definite information and data, it is difficult to assign relative values for the importance of the above three factors. Factors (2) and (3) mentioned above would be served by mixing the refuse with soil or by interspersing thin layers of garden earth between layers of refuse in compost-making. Factor (1) mentioned above, however, would require that the compost should be covered over with a layer of earth on top. In the Bangalore process of compost making, both these methods of using earth are adopted, viz. thin layers of earth in between layers of refuse and an earth plaster on top.

The beneficial effect of earth on carbon economy of compost, has got a practical bearing in relation to the quantity of organic manure that is finally obtained. The amount of organic manure recovered (total manure less earth and ash) is roughly proportional to the amount of carbon recovered; and since the aim of composting is to secure as high a recovery of organic manure as possible (of the proper quality) from the original refuse, the recovery of carbon, under such conditions, could be taken to be a measure of the efficiency of the composting process in this respect.

Since the manure produced by a satisfactory system of compost making generally reaches a C/N level near 10 : 1, the amount of nitrogen that is conserved in the composting process would directly control the quantity of carbon conserved and thus, indirectly, the total quantity of organic manure obtained. Thus, in two systems of compost-making both of which yield finally a manure of C/N ratio near 10 : 1, if the total nitrogen recovery in one system is only 40-50 per cent, and in the other 90-100 per cent, it is clear that the former method of composting would yield only about half the quantity of organic manure yielded by the latter method. The importance of adopting satisfactory methods of preventing nitrogen loss during composting, in order to obtain the highest recoveries of manure possible, is therefore evident.

It is sometimes stated that the losses of nitrogen that take place during aerobic composting would be made up by subsequent fixation from the air, when the material decomposes further; and thus the final efficiency would be the same in all cases. But the experimental data already presented by one of the writers [Acharya, 1939, 1940] would show that in cases where the initial C/N ratio of the refuse mixture is about 30 : 1 or narrower and some of the refuse constituents are rich in nitrogen, e.g. night-soil or urine, the quantity of organic manure finally obtained is considerably greater in the cases where nitrogen loss is avoided. The work of Dhar and co-workers [1937] has shown that cellulosic materials fix from 5 to 10 mg. of nitrogen per gram of carbon decomposed. The difference between the nitrogen loss-cum-fixation system and the nitrogen-conservation-system is brought out schematically in Table VIII and is found to be in favour of the latter system. This is due to the fact that the quantity of nitrogen gained with difficulty by fixation from the air is only a fraction of what is easily lost by adopting defective systems of composting.

TABLE VIII

Carbon and nitrogen economy during composting

100 lb. dry matter of refuse plus urine or night-soil — C=30 per cent, N=1 per cent, C : N ratio 30 : 1

Constituents		Aerobic decomposition with turnings (approximate figures)	Bangalore process (approximate figures)
Initially present	Carbon	30 lb.	30 lb.
	Nitrogen	1 lb.	1 lb.
Present after 1st stage of active decomposition for 2 weeks	Carbon	20 lb.	25 lb.
	Nitrogen	0·5 lb. (loss 0·5 lb. N)	1 lb.
Present after 2nd stage of 3 months' decomposition including N fixation from air	Carbon	7 lb.	11 lb.
	Nitrogen	0·5 lb. +0·13 lb. N fixed from air by 13 lb. of C decomposed Total=0·63 lb. N	1 lb.
Final C/N ratio	..	10·1	11

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SUMMARY

1. Mixed refuse containing weeds, leaves, grass, straw and cattle dung, having a C/N ratio near 32 : 1, was composted aerobically in jars, under controlled conditions, with and without the addition of garden earth.

2. The refuse composted without the addition of earth lost nearly 23 per cent of its initial nitrogen in a period of 20 weeks. The loss appeared to

ur in two stages : there was an initial period of id loss, which covered the first week of decom- ition ; this was followed by a longer period of w and steady loss, along with the progressive omposition of the refuse.

. The loss of nitrogen was overcome by the lition of earth to the compost mass, the over-all ult being a slight gain in total nitrogen, due to tion from the air.

. Parallel with the increased conservation of rogen secured by addition of soil to decomposing ise, there was an increased recovery of carbon l of organic matter in the final manure.

. The C/N ratio of the compost narrowed vn quicker in cases where soil had been added the refuse.

. Probable explanations are offered for : the considerable losses of nitrogen taking place m mixed refuse of C/N ratios wider than 30 : 1, the beneficial effect of earth in controlling such rogen losses ; and (c) the relation between overy of carbon and of organic manure on the hand and of nitrogen economy during com- ting on the other.

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TUDY ON THE ESTIMATION OF THE YIELD OF WHEAT BY SAMPLING*

By A. K. Mallik, V. Satakopan and S. Gopal Rao,† Agricultural Meteorology Section, Meteorological Office, Poona

(Received for publication on 5 April 1945)
(With five text-figures)

any attempt at estimation of crop yields by pling, the fixing up of an appropriate size shape of the sampling unit and of the percen- e area to be sampled are the essential prelimi- ies. If the percentage of total population pled remains the same, the degree of accuracy ined will depend mainly on the size and shape he sampling unit and the distribution of these ts in the general population. The actual shape size of the sampling unit will be largely erned by the order of magnitude of the crop- ting experiments. Thus the administrator is interested in the crop-outturn of large areas to deal in terms of districts and hence the t used by him is bound to be different from that loyed by an experimentalist desiring to mate the yield of an experimental plot. The ct sampling technique, the arrangements of the mate units, the number of units to be sampled the distribution of these in the population, differ in each case as these will depend upon the nature and magnitude of the variability involved. But it should, however, be possible in practice to evolve for any crop, a hierarchy of sampling techniques to deal with cases ranging from individual plants to the district crop as units and covering all intermediate cases. In designing an experiment to give a complete solution of the problem of any one crop, it is possible, at one time to handle only two or three of the stages in the hierarchy.

The present paper deals with one such experiment designed to give information on the most suitable sampling technique for estimating the yield of wheat, variety A115, conducted in March, 1939, at the Government Experimental Farm, Powerkheda, Hoshangabad, C.P., with the kind co-operation of the Deputy Director of Agriculture, Northern Circle, C.P. The experiment is first described and then the important results obtained are discussed.

Material and method

A wheat field, ready for havesting, from the non-experimental area of the farm was chosen. A square plot, 4/10 of an acre, i.e. 132 ft.×132 ft. was marked out for the experiment. This area

*This investigation was made when the Agricultural Meteorology Section was financed by the Imperial Council of Agricultural Research.
†Mr. A. K. Mallik assisted by Mr. Satakopan conducted the field experiment. Mr. Satakopan supervised the statistical computations.

was harvested completely square yard by square yard and the yields of grain and straw were recorded separately from each unit (i.e. 3 ft. × 3 ft.). As the marking of the whole plot into square yards was inconvenient for operations, the plot was sub-divided into 16 sub-plots of 33 ft. × 33 ft. each (1/40 of an acre), leaving a 3 ft. path along two edges of each sub-plot for trampling. The remaining area of 30 ft. × 30 ft. from each sub-plot was first marked out into 100 sq. yd. by strings tied across the sub-plot to pegs fixed at the boundaries of the sub-plot. 1600 sq. yd. were thus separately cut and the grain threshed by hand by labourers. The yields of grain and straw were recorded, correct to 1/16 of an ounce. The plants were cut with knives, and as it was not possible to ensure uniformity among the labourers in the method of cutting, the yields of straw recorded were not strictly comparable. Records of straw yields obtained from the experiment were therefore rejected and only grain yields were taken into consideration.

A plan of the whole experimental plot is shown in Fig. 1. As the orientation of the lines of plants has a bearing on the discussion of the results, the general direction of the rows is also indicated in the plan. The rows were roughly parallel to AB in Fig. 1.

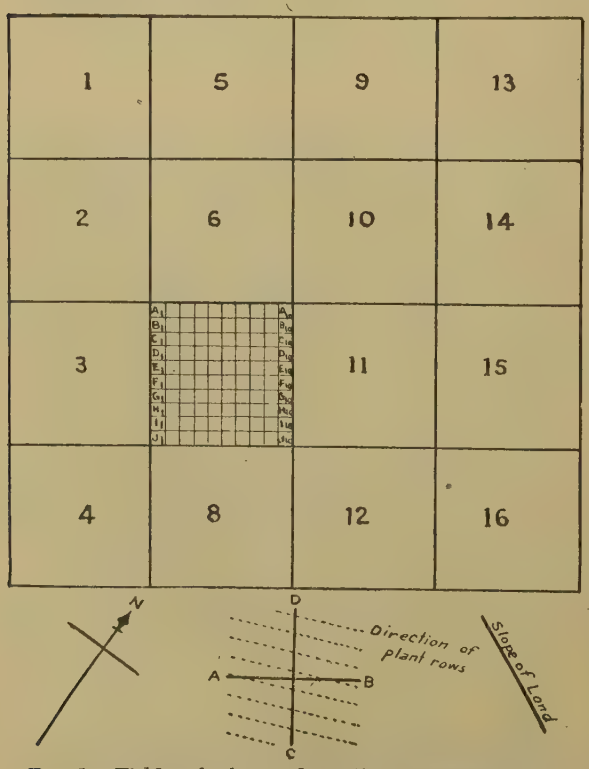

FIG. 1. Field, sub-plots and constituent square yards

It may be mentioned that the yield figures for grain do not represent the yields from 1600 contiguous square yards but suffer from certain discontinuities due to the fact that one yard of the crop was rejected around each sub-plot as this was being constantly trampled during operations. But this discontinuity is not expected to affect the result of the analysis to any serious extent as it is likely to vitiate only the variances between sub-plots to a small extent.

DISCUSSION OF THE RESULTS

Frequency distribution of the yields

In the first place the frequency distribution of the yields was studied. The frequency distribution of the yield from 1600 sq. yd. is shown in Table I and graphed in Fig. 2. The following distribution constants may be of interest in respect of the 1600 yields as a whole.

TABLE I

Frequency distribution of the yield of grain

Weight of grain yield in 1/16 oz.	Number of square yards	Weight of grain yield in 1/16 oz.	Number of square yards
12–13	8	32–33	116
14–15	18	34–35	85
16–17	62	36–37	45
18–19	94	38–39	28
20–21	159	40–41	32
22–23	175	42–43	15
24–25	184	44–45	6
26–27	176	46–47	3
28–29	224	48–49	3
30–31	165	50–51	..
		52–53	2
			1600

Mean yield of grain	..	26·71 (in 1/16 of an oz.)
Standard deviation	..	6·25 (—do—)
Coefficient of variability	..	23·4 per cent.
g_1*	..	0·453 0·019 (S.E.)
g_2*	..	0·278 0·122 (S.E.)

g_1 which is a measure of asymmetry and which has a zero value for the normal distribution is significant for this distribution, being nearly 24 times its standard error. This indicates that the frequency is asymmetric. The value of g_2 is not significant (judged from the 5 per cent level) which indicates that the curve is not materially different from a normal curve in respect of kurtosis, i.e. flatness of the top.

*g_1 and g_2 are constants which measure the asymmetry and kurtosis of a frequency distribution curve. Their values are zero for a normal distribution. [Fisher, 1936].

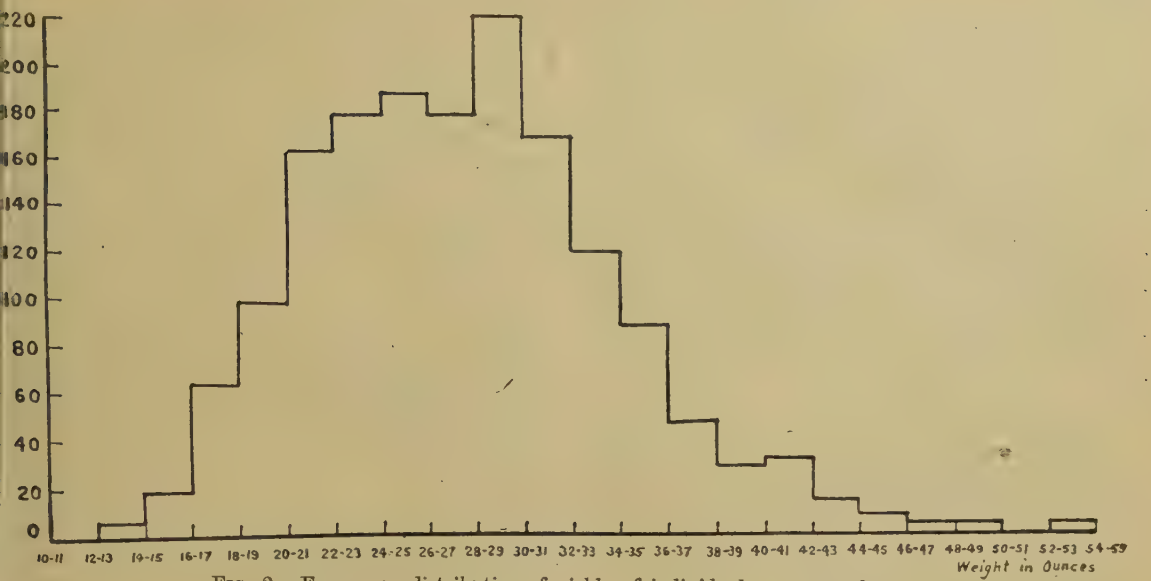

FIG. 2. Frequency distribution of yields of individual square yards

alysis of variance

In order to estimate the variances between units different sizes and shapes, the 1600 sq. yd. ere grouped consecutively into composite units nsisting of 2, 3, 4,.....50 contiguous square rds, and the analysis of variance was worked t for each grouping. For example, for the ntiguous unit of 2 sq. yd., the 100 sq. yd. in each b-plot were divided into 50 units of two square rds each and the allocation of degrees of freedom the analysis of variance was as follows :

	D.F.
Sub-plots	15
Between composite units ..	784
Within units	800
	1599

TABLE II

Different sizes and shapes of composite units studied

erial No.	Size of composite unit	Arrangement of square yards in the unit*	Remarks
1	2	2h	All sq. yards used in each plot
2	2	2v	do.
3	3	3h	The last column at the right end omitted from each plot
4	3	3v	The last row at the bottom of each plot omitted
5	4	4h	The last two columns omitted
6	4	2h×2v	All units used in each plot
7	4	4v	The last two rows omitted in each plot
8	5	5h	All units used
9	5	5v	do.
10	6	3h×2v	Same as item 3 above
11	6	3v×2h	Same as item 4 above
12	8	4h×2v	Same as item 5 above
13	8	4v×2h	Same as item 6 above
14	9	3h×3v	The last column and last row omitted from each plot
15	10	5h×2v	All units used
16	10	5v×2h	do.
17	12	4h×3v	The last two columns and last row omitted
18	12	4v×3h	The last column and last two rows omitted
19	15	5h×3v	The last row omitted
20	15	5v×3h	The last column omitted
21	16	4h×4v	The last two rows and last two columns omitted
22	20	5h×4v	The last two rows omitted
23	20	5v×4h	The last two columns omitted
24	25	5h×5v	All units used
25	50	10h×5v	do.
26	50	10v×5h	do.

TABLE II—*Contd.*

* v= along CD in Fig. 1. and h= along AB in Fig. 1.

These have a reference to the directions on the plan of Fig. 1. For example, 5h×2v means a composite unit of 10 sq. yd. made of 5 yards along AB and 2 yards along CD in Fig. 1.

It should be mentioned here that as the sub-plots have been kept separately throughout the analysis it was not possible to utilize all the square yards from each plot in forming composite units of certain sizes. The available number of composite units of the requird sizes was taken from each sub-plot, the remaining square yards being omitted. The peculiarity in each case in this respect is indicated in the remarks column of Table II. The differences in the total variance and variances due to sub-plots seen in Table III arise also out of this fact, that all the units could not be utilized in forming different sizes of composite units.

The variance between samples in relation to the orientation of the rows

Since the crop was sown with a three-tyned drill, it was considered that the orientation of the lines of the crop will have a bearing on the variances between composite units (i.e. samples) of different shapes. Each size of composite unit has therefore been studied in two or more alternative arrangements of square yards. Thus a composite unit of 4 sq. yd. has been taken first by combining four contiguous square yards along AB (Fig. 1), secondly by combining four contiguous square yards along CD (Fig. 1), and thirdly by taking a compact block of four square yards, two yards by two yards. The different types of composite units considered for each size are illustrated by Fig. 3.

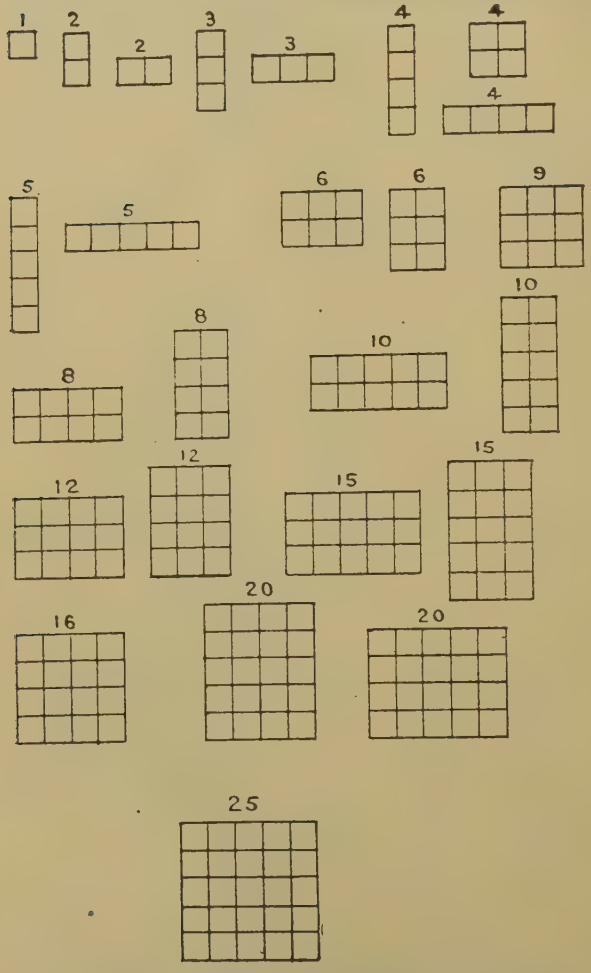

FIG. 3. Size and shape of sampling units obtained by different combinations of square yards

Table III shows the analyses of variance for different shapes and sizes of composite units. It will be seen from column 3 of Table III that for the same size of the composite unit the arrangement of square yards with an elongation along AB gives a greater variance between composite units than the arrangement elongated along CD. Fig. 4 also indicates this clearly. Considering that the rows were more or less parallel to AB (Fig. 1) it appears that there is greater variability between the rows of plants than within the row. This is also confirmed as it should be evident, by the smaller, "within units variance" for the AB elongated units than for the CD elongated units. It would therefore appear that in dealing with the crop it is always better to take a sample elongated in a direction at right angles to the plant rows to keep the sampling variance low.

TABLE III

Analysis of variance of different shapes and sizes of composite units

Size and shape	Variances between sub-plots	Variance between composite units	Variance within units	Total variance
2h	639·3	46·3	20·7	39·0
2v	639·3	44·1	22·8	39·0
3h	584·2	49·5	25·4	39·0
3v	555·2	48·6	25·7	38·6
4h	491·1	68·6	22·2	38·7
4v	476·5	57·0	26·5	39·0
2h×2v	639·3	65·3	23·1	39·0
5h	639·3	74·3	23·6	39·0
5v	639·3	55·7	28·0	39·0
3h×2v	584·2	82·6	24·0	39·0
3v×2h	555·2	73·3	25·7	38·6
4h×2v	491·1	106·3	24·0	38·7
4v×2h	476·7	86·8	26·9	39·0
3h×3v	512·7	96·9	26·0	38·7
5h×2v	639·3	113·7	25·3	39·0
5v×2h	639·3	84·3	28·2	39·0
4h×3v	431·9	126·5	26·2	38·5
4v×3h	437·1	115·1	27·9	39·3
5h×3v	555·2	136·6	27·0	38·6
5v×3h	644·2	113·0	28·5	39·6
4h×4v	366·3	153·4	28·3	39·1
5h×4v	476·5	172·8	28·3	39·0
5v×4h	491·1	145·6	28·9	38·7
5h×5v	639·3	152·5	29·6	39·0
10h×5v	639·3	277·6	30·8	39·0
10v×5h	639·3	138·5	32·3	39·0

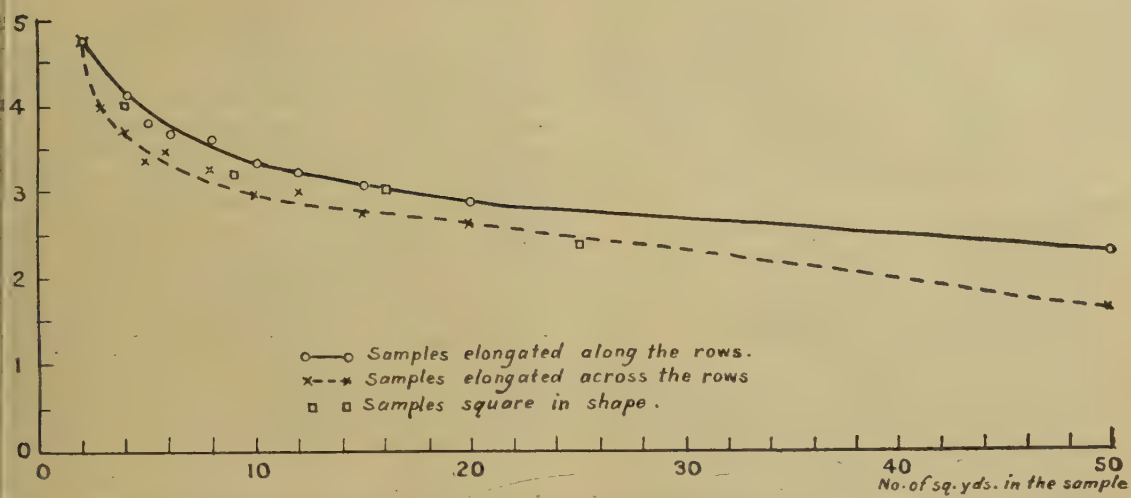

FIG. 4. The standard error of mean yield per square yard ($\sigma_{\bar{s}} / \sqrt{n}$) in relation to the size and shape of the sample

...e optimum size and shape of the sample

Table IV gives the standard error between ...mposite units (square root of variance between ...its) and also the standard error of mean yield ...r each sample $\sigma_{\bar{s}} / \sqrt{n}$ where n is the number of ...quare yards in each sample. The values of the ...andard errors of the mean yields have been ...otted against the size of the unit in Fig. 4 for ...th the AB and CD elongated samples. The ...int representing compact structures of compo... units are shown separately. It is seen from ...g. 4 that $\sigma_{\bar{s}} / \sqrt{n}$ decreases as the size of the ...mple increases, showing that the variability of ... mean yield decreases with size of unit. But ... decrease is greater for small units and as the ... increases the decrease is less. In fact the slope ...the curves for samples larger than 15 units is ...nsiderably less than that of the part of the curve ...presenting smaller units. It appears therefore ...at a sample comprised of 12 to 15 square yards ...ranged in such a way that 4 or 5 rows are ...cluded in the sample, i.e.

... 4 square yards along CD and 3 sq. yards along AB ... 5 square yards along CD and 3 sq. yards along ...3, is a suitable unit for sampling operations on ... crop.

...timation of yield by random sampling

Estimation of the sub-plot yield by choosing ...mples at random from each sub-plot was next ...nsidered. Four square yards were selected ... random from each sub-plot and the sub-plot ...lds estimated from these. Five square yards ...re then selected at random from each sub-plot and the yield of each sub-plot was estimated therefrom. Such experiments were repeated increasing the number of square yards up to 50. In the last

TABLE IV

Standard errors from variances in Table III together with standard error of mean yields for each composite unit

Size and shape of composite units	Sub-plot error	Composite units $\sigma_{\bar{s}}$	Within units	$\sigma_{\bar{s}} / \sqrt{n}$
2h×1v	25·28	6·801	4·545	4·81
2v×1h	25·28	6·639	4·774	4·69
3h×1v	24·17	7·036	5·038	4·06
3v×1h	23·56	6·971	5·068	4·02
4h×1v	22·16	8·282	4·711	4·14
2h×2v	25·28	8·083	4·805	4·04
4v×1h	21·85	7·551	5·145	3·77
5h×1v	25·28	8·618	4·859	3·85
5v×1h	25·28	7·467	5·292	3·34
3h×2v	24·17	9·090	4·901	3·71
3v×2h	23·56	8·561	5·065	3·50
4h×2v	22·16	10·309	4·897	3·64
4v×2h	21·83	9·316	5·185	3·29
3h×3v	22·64	9·844	5·101	3·28
5h×2v	25·28	10·661	5·030	3·37
5v×2h	25·28	9·183	5·313	2·90
4h×3v	20·78	11·25	5·12	3·25
4v×3h	20·91	10·73	5·29	3·10
5h×3v	23·56	11·69	5·20	3·11
5v×3h	25·38	10·63	5·34	2·74
4h×4v	19·14	12·38	5·32	3·09
5h×4v	21·83	13·15	5·32	2·94
5v×4h	22·16	12·07	5·38	2·70
5h×5v	25·28	12·35	5·44	2·47
10h×5v	25·28	11·77	5·68	2·36
10v×5h	25·28	16·66	5·55	1·67

case half of each sub-plot was sampled out and the yield of whole sub-plot was estimated therefrom.

Apart from estimating the plot yields the percentage information obtained for each size of the random sample was calculated by the formula

$$P=100(1-L) \text{ where } L=\frac{n-2}{n}\left(1-\frac{k}{h}\right)\frac{B}{A},$$

where—

P =Percentage information obtained
L =Loss of information
k/h =Proportion of plot sampled
B =Variance between samples
A =Variance between sub-plots
n =Number of sub-plots

For theoretical considerations behind this formula a reference may be made to Yates and Zacopanay [1935].

TABLE V

Results of random sampling of different percentages from sub-plots

Number of square yards sampled from each sub-plot	Standard error		Percentage information obtained	Mean yield per square yard as estimated by sampling in 1/16 oz.
	Plot	Within plot		
4	6·66	5·72	38	26·98
5	7·44	5·91	47	25·30
6	7·27	6·00	44	27·47
7	11·27	5·77	79	26·83
8	10·58	5·46	79	26·77
10	9·88	5·83	73	27·16
12	11·67	5·90	80	27·49
14	11·14	6·11	77	26·78
16	10·99	5·58	81	26·80
20	12·90	5·85	86	26·46
25	13·92	5·66	89	26·79
30	14·07	5·65	90	26·67
40	16·64	5·77	94	26·62
50	18·10	5·93	95	26·67

Actual mean yield per square yard in 1/16 oz.=26·71

Table V gives the estimated and the actual mean yield per square yard for the different sizes of sample together with the percentage information obtained. It is seen that sampling 12 to 15 per cent of the crop gives a percentage information of the order of 80. The relationship between the percentages of total population sampled and the information obtained is shown graphically in Fig. 5. It will be seen that the increase in the percentage information obtained is rapid till the per cent population sampled reaches a value of about 12 to 15 per cent; further increase in percentage sampled increases the percentage information at a slower rate. Here again it would appear that sampling about 12 to 15 per cent of the total population will give a fairly good estimation of sub-plot yields.

Random sampling with composite units

Next, the question whether composite units can be used for sampling and if so, what will be the best size and shape of the units to be taken was studied. Table VI gives the results of the analyses for three percentages of sampling 12, 15 and 16 per cent. For each percentage of sampling, composite units of different sizes have been taken and the percentage information obtained by the sampling has been worked out. It will be seen that the following sampling techniques give over eighty per cent of the information.

Size of composite units	Number of composite units
1. 4 contiguous square yards across the rows along CD	4
2. 2 sq. yd. along CD	8

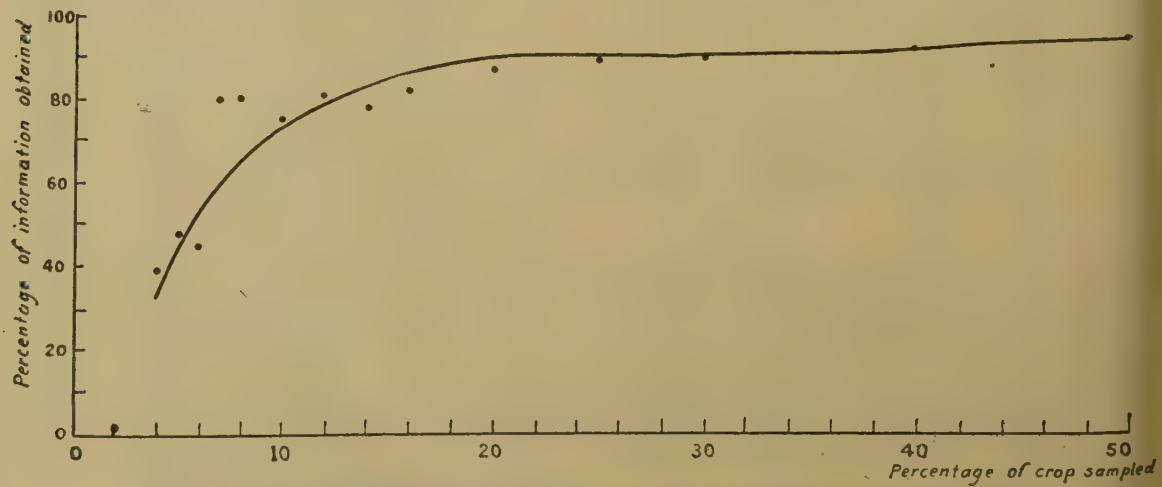

FIG. 5. Percentage information obtained in relation to the percentage of crop sampled

TABLE VI

sults of random sampling with composite units for 12, 15 and 16 per cent sampling

position composite unit	No. of units selected at random	Standard error* per composite unit		Percentage information	Percentage sampled to total yield
		Plot	Within plots		
2v	6	16·75	8·95	78	11·95
2h	6	13·81	8·48	71	12·02
3v	4	21·91	14·37	68	12·12
3h	4	22·83	13·39	74	11·79
4v	3	18·66	13·87	58	12·06
4h	3	26·94	16·33	72	12·07
2v×2h	3	27·71	24·81	38	11·51
6v	2	22·21	21·62	28	11·78
6h	2	23·04	20·94	37	11·63
3v×2h	2	27·43	16·91	71	11·95
3h×2v	2	25·34	18·25	60	12·04
3v	5	22·06	12·26	77	14·79
3h	5	21·88	11·68	79	14·64
5v	3	20·58	18·73	39	15·23
5h	3	24·59	17·96	61	15·05
2v	8	17·54	8·37	83	16·24
2h	8	14·22	9·41	68	15·61
4v	4	27·71	12·64	85	16·10
4h	4	27·34	15·03	78	15·96
8v	2	41·59	28·11	67	16·08
8h	2	35·30	29·02	51	15·67

he standard errors are based on the analysis of variance f total yield of each composite unit and not reduced to r square yard. Hence the standard errors for different es of composite units are not comparable without eduction to the same size.

The second arrangement would involve double the number of units to deal with and so the first is preferable from the point of view of practicability. It would thus appear that for estimating yields by random sampling, four units of 4 sq. yd. each (4 yd.×1 yd. the length being at right angles to the rows) from each sub-plot will be most suitable.

SUMMARY

The present paper deals with a complete harvesting experiment with the object of finding out the most appropriate size and shape of sample to be used for the estimation of the yield of wheat by sampling. The procedure adopted is described in detail. Statistical analysis of the data shows :

1. Samples elongated across the rows are less variable than those elongated along the rows.

2. The optimum percentage of total population sampled is about 16 per cent. There is no material gain in information by sampling more than 16 per cent of the crop.

3. Samples composed of 3 yd. along the rows and 4 or 5 yd. across the rows are the most suitable.

ACKNOWLEDGEMENTS

Our best thanks are due to Dr L. A. Ramdas, Agricultural Meteorologist for suggesting the problem and for guidance in the preparation of this paper. Thanks are also due to Dr R. J. Kalamkar, Deputy Director of Agriculture and the staff at Powerkheda Experimental Farm, Northern Circle, C.P., for their kind co-operation.

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PLANT QUARANTINE NOTIFICATION

Notice No. 1 of 1945

THE following Quarantine Regulations have been received in the Imperial Council of Agricultural Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi.

(1) Plant Quarantine Import Restrictions of the territory of Southern Rhodesia—B.E.P.Q.446, Supplement No. 1 dated the 3rd November, 1944, issued by the United States Department of Agriculture.

(2) Plant Quarantine Import Restrictions of the Republic of Peru—P.Q.C.A.310, Supplement No. 6, Revised, dated the 16th November 1944, issued by the United States Department of Agriculture.

(3) Service and Regulatory Announcements April-June 1944, B.E.P.Q.159, issued by the United States Department of Agriculture.

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Articles intended for The Indian Journal of Agricultural Science should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state ' Original not seen '.

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